RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXIV.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA, AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1890.

PENINSULAR INDIA.

Mr. Foote.

MADRAS PRESIDENCY.—*Crystalline and Transition Series.*—The auriferous condition of the Dhárwár series in the Anantapur and Bellary districts has been the main subject of economic survey, and concomitant with this enquiry the areas of the Dhárwár rocks in those districts have been as closely demarcated as time would allow in the hands of the single officer of the Survey now left to carry on the work in Southern India.

Completion of Bellary-Anantapur belts of Dhárwárs.

Mr. Foote reports that by the beginning of 1890 he had completed the examination of the taluks of Harapanahalli, Haddagalli, Kudligi, and Riadrug, forming the southern half of the Bellary district. The field season was concluded in the Anantapur district, where an area of 200 square miles was mapped out in following up the southerly extension of the Penner-Haggari band of Dhárwárs.

In these regions the auriferous indications were not worthy of any particular notice; and the conclusion is, that future development must rely on the more promising tracts already pointed out by Mr. Foote.

Examination of belt in the Cuddapah district commenced.

On the south-west edge of the Cuddapah district, in the Kudiri taluk, I myself long ago noted the occurrence of a series of sub-metamorphic rocks which Mr. Foote's later investigations showed must also be of the Dhárwár series; while we have both from time to time surmised that this occurrence might possibly be a northerly extension of the well-known and productive belt of Kolar in Mysore. The completion of the Bellary-Anantapur area now allows of this Cuddapah tract, which is in British territory, being surveyed, and Mr. Foote has commenced the present field season with that object.

Old gold mines at Kolegal, Coimbatore district.

Another gold region in which the granting of mining concessions has been before the Madras Government, in the Kolegal taluk of the Coimbatore district, has long waited for authoritative opinion; and in October last Mr. Foote was enabled to make a preliminary inspection. He found, however, that this tract of old mining is not in the

Dhárwár series; in which respect it seems to resemble the Wainad region, which is peculiar and unique in having its auriferous reefs developed in the crystalline or gneissic series. The further examination of this tract will be taken up later on in the year.

Iron.

Considerable additions were made to our knowledge of the occurrences of iron ore in the Dhárwárs, particularly in the Kunchur tract south-west of Hadagalli.

Pot-stone.

Amongst the crystalline or gneissic rocks, several large and important bands of pot-stone were examined in the Harapanahalli area. The most extensive band occurs at Nilgunda, seven miles to the west-south-west of Harapanahalli. The rock is often fine-grained and homogeneous enough for architectural carving; but no particular development of the finer steatitic form was noted.

Other occurrences are reported, which will, however, be described in detail in Mr. Foote's forthcoming memoir on the Bellary district.

Fault-rock; cupriferous at times.

The very numerous and great runs or walls of fault-rock traversing the crystalline area are a conspicuous feature in the Bellary country; though, contrary to expectations, they are only rarely metalliferous, and then usually with iron ore to a poor extent. In the great 12-mile dyke or ridge north of Harapanahalli, however, the numerous interstices of the rock are locally filled by films of rich green carbonate of copper. At one place, on the slope of the ridge near the Nandi Bevur-Itugi road to Bellary, are two old open workings from which the ore had been raised in some quantity n times of which there is no recollection or tradition now.

Chhattisgarh coal fields. Ib coal.

Central Provinces.—*Lower Gondwana.* Although there is now no Survey party in this division of Peninsular India, the Department has not thrown off all connection with any future development of the Chhattisgarh coal fields. Renewed interest has been aroused, by the striking of a seam of coal in the foundations of a bridge over the Ib river during the progress of construction of the Bengal-Nagpore Railway, though much importance was not attached at first to this find, because that part of the country had already been surveyed and tested by a series of borings which pierced several thick seams of coal and carbonaceous shale of too inferior quality to encourage further exploitation.

The Ib bridge find was, however, followed by the digging of a small pit; whence a reported trial of the coal gave such favourable results that arrangements were made for me to visit once more this field, in which I had myself failed to strike any sufficiently promising seams. This small pit furnished continuous samples of 8 feet of apparently uniformly good coal, on which I advised as to a system of boring should any of these samples be favourable; but, after all, even this coal was found to be not of much better quality than that already known in the field. Still, its uniformity and thickness are in its favour; and, above all, it was certainly better than the coal then being used on the railway from the Warora colliery. Several other borings have been put down by the railway authorities, but it is doubtful as yet whether this particular seam has been met with again; while a very thick seam, purporting to be all coal, of some 40 odd feet in thickness, has been struck quite near the surface. No samples of this thick seam have yet been sent down to the Survey for examination; but it will probably turn out that much of it is only carbonaceous shale, and that it is the same seam which I had already tested at Ghanamal near the broad exposure in the Lilari river.

Utilization of the Survey boring machines.

In the meantime, one of the two sets of American steam-boring plant sent out to this Department by Her Majesty's Secretary of State has been lent to the Bengal-Nagpore Railway Company for further exploration. There can be no doubt of the almost illimitable quantity of coal in this field, but nothing more can be reckoned on as to its quality than that it may in places be better than the Warora coal; all the good samples I have seen, with the exception of the Ib bridge, being only from thin bands associated with a preponderating thickness of poorer fuel or useless carbonaceous shale. It still remains to find a fairly uniform thickness of coal in the seam answering to that struck in the small pit at the Ib bridge.

Messrs. La Touche and P. N. Bose.

Daltongunj coal-field. Utilization of second set of Survey boring-plant.

BENGAL PRESIDENCY.—*Lower Gondwana.*—Renewed enquiry having been instituted as to the capabilities of the Western Bengal coal fields, in view of the construction of a line of railway between Howrah and Moghulserai, the Daltongunj coal field has become the scene of fresh research. Towards the end of the year Mr. La Touche was deputed to the geological part of the work; that is, to select sites for borings and trial pits, a series of which he has accordingly arranged. Active operations have been commenced, while the second set of American boring-plant has been lent to the Department of Public Works for the furtherance of the work.

Hura coal field, Rajmahal. Borings relinquished.

The trial borings in the Hura field of the Rajmahal tract near Semra have resulted in the abandonment of that exploration. I visited the place in January last in company with Mr. Atkinson, of the firm of contractors who had undertaken the work, and pointed out two sites of the set of three borings which were contracted for. Unfortunately, the operations were again and again delayed for a considerable time through loss of boring tools: the results being that two of the holes were run down to 142 and 300 feet respectively. The first failed utterly through the whole string of tools being lost in the hole, and no fresh hole in that locality has been sunk, although I had expected that such would have been carried out eventually. The second hole, further to the deep by 600 yards, was then run down 300 feet; and two coaly seams were reported as struck at 200 and 209 feet. The samples sent down yielded over 31 per cent. of ash, showing that the coal, such as it is, is unfit for fuel. The poor coals already struck in the previous borings in 1889 were all near the edge of the field; but it was to be expected that there might have been some improvement in the quality of any higher coal further from the edge of the field. The last boring has dispelled such anticipation. I am obliged therefore, however reluctantly, to come to the opinion that there would be no gain by prosecuting any further search by boring at this part of the western side of the Rajmahal country.

Darjiling coal. *Mr. P. N. Bose.*

During the past season Mr. Bose has steadily and successfully explored the coal area to the southward of Kalimpong in the Darjiling district between the Sisu and Ramthi rivers, a very detailed report on which appeared in the Records of the Geological Survey of India for November last. A sum of Rs. 2,000 was sanctioned by the Bengal Government for the exploration; and considering that Mr. Bose' tested the ground by over a hundred shallow pits and trenches, coked the coal in the field, and opened paths and clearings in the exceedingly close jungle of this overgrown tract at the foot of the hills at an expenditure well within that sanction, the whole exploration was managed with admirable economy.

As a rule, the coal is very high dipping and much crushed, while faults are numerous: thus, the working of it will be very difficult and precarious. The quality of the coal is, however, good, and a great part of it can be coked. It would appear that there may be some $5\frac{1}{2}$ million tons available of good coal, while it is estimated that 20 million tons may be set down for the whole explored area of a little over one square mile.

Mr. Bose divides his coal into three classes—A, B, and C—of which A cakes strongly, the percentage of ash not exceeding 16, while B cakes strongly, and has between 16 and 22 per cent. of ash.

Of the principal coal seams, not less than 5 feet in thickness, as indicated by his pits, all belonging to classes A and B, he counts about 25; although his calculation for $5\frac{1}{2}$ million tons of coal is based only on 11 seams.

During the original enquiry after this Darjiling coal, when thin seams were known as occurring in the neighbourhood of Teendaria and other places, a very poor opinion was formed as to its capabilities, and the best that was thought of it was that it might be compressed into bricquettes. The later finding of seams of from 16 up to 27 feet in thickness was far too encouraging, however, to leave the utilization of the fuel an open question, to be tried merely by samples in the laboratory: so Mr. Bose took the opportunity of spending some days at the coking operations at the Sanktoria colliery near Barakar; while a small press was most obligingly lent him by Messrs. Burn & Co., of Calcutta. The pressing of the coal was a failure owing to some fault in the press; but the coking experiments, which were carried out in the field, in three open kilns of good size, were completely successful.

Thus far,—and that is as far as geologists can report on a coal field,—the survey of the Sisu-Ramthi area is finished: it remains for actual coal mining, which can of course be carried out best by colliery engineers with experience of high-dipping coal.

EXTRA-PENINSULAR INDIA.

Mr. R. D. Oldham and Sub-Assistants Hira Lal and Kishen Singh.

BALUCHISTAN.—*Tertiary.*—Mr. Oldham carried on the survey throughout the year, and added very considerably to our knowledge of the coal, oil and water resources in British Baluchistan.

Early in the year his work still lay in the Harnai valley, and a special report on the more favourable sites for Petroleum explorations in the Harnai district was published in the May number of the Records, following on a general description of the mode of occurrence of the petroleum and his reasons for believing that it exists in workable quantities, which description appeared in the following number of the same publication.

Location of oil sites in the Harnai valley.

Three localities were indicated at Spintangi, Pir, and Kipar Mand; although, taking all things into consideration, he is in favour of the second locality being adopted for the commencement of exploration. In any case, the depth of boring would be very considerable, 1,000 feet or more, according to the situation, though this can hardly be considered a prohibitive depth in such close proximity to the line of railway.

I went over the whole ground with Mr. Oldham in March, and was struck with the remarkable display of shows of dried-up oil in the limestones of the particular localities pointed out, while all his reasoning and expectation thereon appeared to me to be fairly justified. There is, in fact, little doubt but that a large store of oil lies within profitable reach of this part of the Sind-Pishin railway.

During his examination of the Bolan pass in February and March, Mr. Oldham was led to make the following remarks on the oil locality near Kirta:—"At the foot of the hills west of the dâk bungalow there are extensive deposits of travertine which have evidently been deposited by hot sulphurous springs, which have now ceased to flow, though warm gas still oozes up through the travertine and can be recognized by its smell. It is difficult to say why these springs issued there: no certain indications of a fault can be found, and one of the springs issued formerly from the hillside, 250 feet above the top of the talus fan at its base. They occur along the outcrop of the band of sandy limestones and calcareous sandstones with *belemnite*-bearing shales at their base.

Bolan valley: oil.

"These travertine deposits are impregnated to a marked degree by petroleum, and on the strength of these surface indications a bore-hole was sunk in the spring of 1889. It penetrated the *belemnite* shales; and at 360 feet a copious spring of hot sulphurous water was struck, and a small amount of oil obtained. The derrick was shifted, but no second boring was put down.

"In view of the importance of discovering petroleum in workable quantity near the line of railway, it is important to discuss the probability of its so occurring near Kirta. A careful examination of the outcrops has convinced me that the petroleum which impregnates the travertine and surface soil was not derived from any rock now exposed at the outcrop, but was brought up from below with the hot water of the springs. Further, from the occurrence of an abundant supply of hot sulphurous water, which, when released by the bore-hole, flowed freely at the surface, it would seem that these springs have ceased to flow owing to their channels having been blocked up by a deposit of travertine. If this conclusion be correct, any boring sunk along the line of these old springs would be likely to be troubled with hot acid water, which would rapidly corrode the casing of the bore-hole.

"A bore-hole sunk further out in the valley might escape this trouble. On the other hand, it is impossible either to determine with certainty the structure of the beds underlying the valley gravels, or to give any estimate of the depth to which it would have to be sunk."

An important and somewhat hopeful result has been attained concerning the occurrence of oil in the Sherani country, on the north-west side of the Sulaiman range.

Sherani country: oil.

In the first instance, a small bottle was sent to the Department in January 1890, labelled "Sample of raw mineral oil, procured by Police Sergeant Shehr Dil Khan, from a place in the Sherani hills, called Terai, about a mile from the Chin Kheyl village of Mogul Kot, 15 miles out of British territory. Forwarded from Dera Ismail Khan by F. Broadway, Esq., District Superintendent of Police, on the 2nd December 1889."

On being tested in the Survey laboratory, the sample was pronounced *not crude*, but a commercial kerosene oil of Russian origin.

Independent testing of another sample by Dr. Warden, Chemical Examiner to the Government of Bengal, gave rise to even a more confirmed suspicion that the oil was a commercial article.

Subsequent enquiry resulted in a further sample being sent down to Dr. Warden in August last: a report on which was given by him, dated 30th September 1890, the penultimate paragraph of which is:—"Assuming this sample of oil to be what it is stated to be—crude petroleum, its value commercially, if it can be procured in sufficient amount, can hardly be over-estimated. A large supply of a natural oil of this quality would simply drive out all foreign oil from the market; there could be no competition."

Ultimately, Mr. Oldham was enabled to visit the locality during the late Zhob Valley Expedition, in November last. His preliminary report shows that the petroleum near Mogul Kot issues at several spots from a band of hard, unfossiliferous sandstone, probably of cretaceous age. The actual overflow of oil at the springs is probably small, not more than ten gallons a day. The oil is clear, limpid, of a pale-yellow colour, and, as it issues from the rock perfectly free from water. He considers there is no reason for doubting that the samples examined in Calcutta were genuine samples of the oil.

His general conclusions are that there can be no doubt of the existence of oil of excellent quality and great value in the district, but that it would be premature to undertake any expensive operations at present.

The sample sent down by Mr. Oldham has been tested in the Survey laboratory by Mr. T. H. Holland. who has furnished a full report: but his results do not supplement Mr. Oldham's estimate of the oil as favourably as might have been anticipated. He considers, after giving all details of the examination, that "as compared with other samples obtained from this district, the specimen sent by Mr. Oldham must be considered to be decidedly inferior in quality."

The enquiry, therefore, cannot be considered otherwise than as yet but very preliminary; and it must remain so until a more thorough examination of the locality and its conditions can be carried out.

Exploration for coal in the Baluchistan region has been prosecuted in the Bolan valley, and in the hills east and south-east of Quetta.

Bolan coal.

The coal seams of the Bolan are practically confined to the neighbourhood of Mach; and, as in the Harnai valley, the limitation of the distribution of the coal seems to be due to the original limitation of the conditions under which it would be formed. South of Ab-i-gum, nothing beyond an occasional exposure of carbonaceous shale or thin layers of coaly matter has been observed.

The coal exposures eastwards of Mach have long been known, and have been worked in a small fitful way for several years. A grant of land in the Hannar valley was made to Messrs. Beahan and Wright, and some drifts made by them in a coal seam gave the following section:—

	In.
Coal	7
Shale	3
Coal	8
Sandstone	3
Coal	4

The beds are highly disturbed, and the coal is too thin and irregular to pay for anything but surface workings, from which a certain amount of coal fit for brick and lime-burning could be extracted.

Exposures of small seams are frequent; but those of any value few. In the Bolan river, on its left-hand bank, some two miles below Mach, the following sections are seen:—

		Ft.	In.
	Shales	0	0
	Coal	1	3
	Shale	1	10
	Coal	0	10
	Shale and carbonaceous shale	15	6
(*a*)	*Coal*	1	11½
	Clay	0	3
	Coal	0	2
	Shales, carbonaceous in part, with shell marl at base	6	10
(*b*)	*Coal*	0	7
(*b*)	Carbonaceous shale	0	6
(*b*)	*Coal*	0	3
(*b*)	Carbonaceous shale	0	3
(*b*)	*Coal*	0	10
	Shales	0	0

Samples were taken from the seams (*a*) and (*b*), which give the following results, in a field assay:—

	(*a*)	(*b*)
Moisture	5·0	8·5
Volatiles	42·0	30·5
Fixed carbon	48·5	41·5
Ash	4·5	13·5
	100·0	100·0

Neither sample caked.

The dip here is 45°, and for systematic working the beds seem less favourably placed than the next locality to be mentioned; but a good deal of coal might be easily got at the surface were it needed for brick and lime-burning.

At the southern end of the Bohr hill the beds have a dip of only 20°; and in the westernmost of the valleys, which drain southwards, Kishen Singh found a coal seam giving a total of 2′ 9″ of coal and 1′ 1″ of partings. The number of partings would make it somewhat troublesome to work, but the low dip and proximity to the railway are distinctly in its favour.

A field assay of a fair average sample yielded:—

Moisture	7·5
Volatiles	48·5
Fixed carbon	38·0
Ash	6·0
	100·0

The only samples procurable were highly weathered, and powdery. The coal did not cake in the assay, but it is possible that the unweathered part might cake in a proper oven, while the quality would doubtless improve, especially as regards moisture and ash, if the seam were opened.

In a progress report of the examination of the hills east and south-east of Quetta, made in April and May, Mr. Oldham states that coal occurs in tolerable abundance in the area under description, but that the seams are, as usual, thin, and the dips high.

Zarakhu valley, E and S. E. of Quetta: coal.

The best coal, as regards both quantity and quality, is found in the Zarakhu valley. It occurs cropping out along the slope of a hillside with a considerable dip.

Along most of the outcrop traced, the coal could be worked by adits to a depth of about 200 feet, more or less, according to locality; and taking another 200 feet to the deep, the data give a result of 400,000 tons, gross, of which 200,000 may be taken as available. Allowing for possible extension of workable coal beyond the outcrop traced, it would not be possible to raise the estimate of available coal beyond 300,000 tons, and another 35,000 tons may be added for every additional 100 feet worked to the deep.

The coal, as shown by the assays, is of excellent quality, with a very small proportion of ash; but it is, like all the nummulitic coals of Baluchistan, very friable and difficult to light.

A more serious drawback to its utilization is its distance from the railway. In order to work it to advantage it would be necessary to lay down 15 miles of tramway, to a point on the railway 20 miles from Quetta. By road the distance to Quetta is 22 miles, and the cost of pack carriage for this distance would be prohibitive. In spite of these drawbacks, the importance of obtaining fuel on the Quetta plateau, and of saving the cost of carrying coal np the ascent, is so great that it may, under certain cicumstances, be found advantageous to work it.

Coal was also found high up on the hillside west of the As Tangi valley, at a point 4 miles north of the Pinki hill, by Sub-Assistant Hera Lall, who records the following section:—

	Ft.	In.
Coal	3	0
Shale	13	0
Coal, with thin layer of gypsum	2	10
Shale	0	1
Coal	2	0
Shale	0	1
Coal	0	9
Shale	5	0
Coal	2	0

Such thick seams of coal have not been met with in the tertiary beds at any other locality, so there is a suspicion that the thicknesses measured at the surface are not the true thicknesses, but due to slippage and disturbance. It is evident, however, that there is a fair quantity of coal here, but the locality is rather inaccessible.

In the Gunduk valley there are numerous exposures of coal, one of which is being worked by Messrs. Rustomjee and Co., but most of these are inaccessible, and small in thickness.

Messrs. C. S. Middlemiss and P. N. Datta.

PUNJAB.—Until the end of the working season, in May last, the elucidation of certain obscure points in the geological history and structure of the Salt Range was left to Mr. Middlemiss, who was ably seconded by Mr. Datta, in the tracing out of particular beds and the collecting of fossils.

I was led to infer that trouble might arise in the working and output of the Dandot colliery, which might necessitate additional opening in other parts of the field; and though I myself did not anticipate any very serious move of this kind, Mr. Middlemiss was advised to investigate the conditions of certain coal, or carbonaceous outcrops, along the foot of the hills.

Salt Range coal.

These outcrops are however so small, and indicate such a faulted condition of the beds, with a corresponding very deep and unknown position of them under the plains beyond, that no hope can be entertained of their profitable development.

In the meanwhile, as I was informed by the Director of the North-Western Railway, the working and output of the Dandot coal is quite satisfactory enough for the present requirements: any diversion from the present area of operations is therefore unnecessary.

During the early part of the year, and for some time previously, the Department had been over and over again referred to regarding samples of crushed coal and carbonaceous shale sent down from the neighbourhood of Abbotabad in Hazara; where also drifts and other small mining operations had been tried, though with very unsatisfactory and unpromising results.

Hazara: coal.

The hot weather of the Salt Range regions being on, I resolved to place Mr. Middlemiss at once in the more favourable climate of this Hazara coal tract. The coal is of like age with that of Dandot; only, as is more generally the case on the North-West Frontier, with these nummulitic exposures, the amount of folding and fracturing of the strata is so very considerable that but poor hopes were entertained by us of any thickness, or continuity of such seams as were known to occur.

Mr. Middlemiss' survey seems, however, to indicate rather more favourable conditions, though they are still poor; and he saw sufficient to enable him to issue a preliminary note, which appeared in the November part of the Records. His conclusion is, that the circumstances of the very high dip of the coal, and the frequency of complicated faults, will necessitate deep and expensive working; though he holds a sanguine belief that a large supply of serviceable fuel may be extracted from the outcrops.

As soon as the surrounding country, which presents considerable difficulties to close survey owing to its hilly and deeply denuded character, is fully examined, a more full report will be issued.

BURMA.—The tin exploitation in Tenasserim under Mr. Hughes is still being carried on; but under considerable disadvantages in the way of climate and insufficient means of communication.

Messrs. T. W. H. Hughes and Dr. Noetling

Mr. Hughes furnished a report on the season's operations up to 1st May 1890, which gives a most grievous tale of delays of all kinds arising out of the difficulties in engaging prospectors and Chinese workmen from Penang. Ultimately, the party, with M. Emile Hardouin as prospector, arrived at Mergui on the 29th November 1889. They visited Thabawleik, penetrating on their way back some of the lateral valleys of the Tenasserim river; and prospected Kahan hill. By the end of December they had left Mergui and reached Kyinmezeik, where they carried on the prospecting of the district as expeditiously as possible.

Tenasserim: tin exploitation.

The results arrived at are, in Mr. Hughes' opinion, only sufficiently encouraging to recommend the demarcations of small plots in the Ply-ngau valleys and Bauhuni tracts for the Chinese system of working. Land rich enough for operations under European management has not yet been met with. He even gives this opinion with reluctance, as it has really been impossible to examine a sufficient area for full consideration of the question of ultimate success.

Mr. Hughes had to take special leave for six months, from which he was permitted to return to Mergui, *viâ* Penang by the middle of November, picking up the prospecting staff and workmen on the way.

The latest information, up to the 1st of January, is, however, more encouraging; in that the returns of tin since the resumption of operations are much better than hitherto, while some excellent ground has been found.

Upper Burma: coal, oil, ruby and tourmaline mines.

Dr. Noetling was engaged in field work from January (when he left Calcutta for Burma) to the end of August, in directing the demarcation of the oil-bearing tracts in the Magive, Mingyan and Pakkoku districts, and in surveying the coal fields, ruby and tourmaline mines in the Shan states. During September he was engaged in the office of the Financial Commissioner of Rangoon, in compiling his notes; and since the beginning of October he has been again occupied with the demarcation of the oil-fields. He has submitted the following reports to the Financial Commissioner, Burma:—

On the Coal-fields of the Northern Shan States.
On the Namsaka ruby mine in the Mainlon States.
On the Tourmaline mines of Mainlon.
On the Salt spring near Bawgyo (Theebaw).

Increase of the Burma party.

The Burma party has been further increased by the deputation of Dr. Warth, late of the Forest Department, who was transferred to the Geological Survey of India, on return from furlough. Mr. Lake will also, on his return from leave, join the contingent.

Geological investigation.—As may be inferred from the preceding resumé of the field operations of the Survey, the larger, and indeed more important, results have been in economic research. Still geological investigation has not been allowed to stand still; and some advance has been made in Baluchistan, the Punjab, and Burma.

In Baluchistan Mr. Oldham has removed some of the obscurity hanging over certain vexed questions which remain since the journeys, and following reports, of W. T. Blanford and Griesbach in the Bolan, Harnai, Quetta, and Kandahar country during 1880-82. His studies were distributed over three tracts, *viz.* in the country adjoining the Sind-Pishin Railway between Sharigh and Spintangi, and between that and the famous oil region of Kattan; in the Bolan valley; and, lastly, in the hills east and south-east of Quetta.

A very interesting report on the Sind-Pishin and Kattan region was published in the August part of the Records, wherein he describes the stratigraphy of the rocks of the following groups (descending order):—

Tufa deposits.
SIWALIKS. Recent and sub-aërial gravels.

(Unconformity and overlap).

NUMMULITIC.	Spintangi limestones (with shales); not always easily separable as a group. Ghazij shales. (Locally coal-bearing; fossil plants and shells; deltaic, 1,000 to 3,000 feet in thickness.) Dunghan limestone. (Upper beds fossiliferous; 500 to 1,800 feet thick.) Chuppar shales.* (Fragmentary plant remains; traces of contemporaneous volcanic activity.) Unfossiliferous limestone. (Oldest rocks seen in Harnai valley.)

In the Bolan the structure of the country is much more complicated than that of the Harnai. Here the oldest rocks are limestones, associated near their upper limit with sands and argillaceous shales of cretaceous age. In a section near Churi the presumably upper cretaceous rocks are directly overlaid by a pale fossiliferous limestone, containing numerous nummulites and alveolinæ of the upper nummulitic type, which relation would, if the upper nummulitic age be determined, establish an unconformity between the two.

The groups of the nummulitics, as made out in the Harnai valley, are fairly recognizable, though considerable variation in their facies is met with in places.

The Ghazij group is very characteristically represented in the neighbourhood of Mach. The coal is accompanied by sandstones, and numerous fossils, but seems to be on a lower horizon than that of Sharigh and Harnai.

Near Bibinani the clear limestones of the Spintangi group are overlaid by nummuliferous limestone of the Nari group, whose presence had already been recorded by Dr. W. T. Blanford.

There are numerous extensions in this Bolan valley of disturbed gravels, raised above the level of the recent gravels, which Mr. Oldham considers must be regarded as of Siwalik age, and show, in a most striking manner, the absolute continuity of conditions of deposition between the latter half of the tertiary, and the recent periods, which is a feature of the geology of the countries north and west of the Indo-Gangetic alluvium.

As regards the hills east and south-east of Quetta, the rocks belong to the same groups referred to above, the high hills overlooking the Quetta plain, and the Dasht-i-bedaolat being of compact limestones of cretaceous age.

The Nari group occurs overlying the Spintangis, and resting directly on the Ghazij shales.

In this area Mr. Oldham has retained the local names of Ghazij and Spintangi for two of the groups of the nummulitic series. The palæontology of these groups has not been worked out, but careful consideration of their lithological character, and their position in the series, leaves, he considers, little reason for doubt that they represent the Ranikot and Khirtar groups of Sind respectively.

Mr. Middlemiss' work in the Salt Range will, to some extent, have the effect of modifying Dr. Waagen's generalizations arising out of the rather meagre materials he had before him for his latest views on the age of the Neobolus beds. After the Obolus beds and the Conularia bed had been fully examined; the more central and western parts of the area were gradually taken in hand, with the main object of following out the Boulder bed through its many appearances, keeping its relation to the Olive series, Conularia beds and Speckled Sandstone in full view as much as possible; and in gathering data concerning the positions and habits of the

Salt Marl, with reference to the contiguous formations. The results are given in his notes on the Geology of the Salt Range, published in the current number of the Records.

Whilst engaged on the coal in Hazara, he took the opportunity of examining the metamorphic and granitic rocks in the neighbourhood of Mansehra and Gorhi Habibullah. The question of their age, and that of the Tanols, as well as of their inter-relations, was gone into. The general results favour Mr. Wynne's idea of the oneness of the Tanols and Infra-Trias of the Sirban; which necessitates a great inversion of the schists, bringing them by a fold-fault in apparent superposition only above the Tanols, the latter being in normal order, and in some places showing a basal conglomerate of slate fragments similar to, though finer than, that at the base of the Infra-Trias of Sirban. The results of the examination of the gneissose rocks prove them to be granitic and intrusive in the schists. They are full of included fragments, and inosculate at their boundaries with the schists. Their resemblance to the gneissose granites of other parts of the Himalaya is very strong.

In Burma Dr. Noetling's discovery of fossils in a series of limestones on the outskirts of the Shan plateau, east of Mandalay, which he had already noticed as bearing a very strong resemblance to certain limestones of the lower Silurian system of Sweden and Western Russia, is of the greatest geological interest and importance. He recognized 2 species of *Crinoidarum*, a gigantic species of *Echinosphærites* and an *Orthoceras*, and considers that these few fossils, however few in number and fragmentary they be, prove certainly the lower Silurian age of the red and greenish-gray limestones occurring a little beyond the 24th mile on the road eastward from Mandalay.

The following generalization of Dr. Noetling on this occurrence is well worthy of note :—

> "The presence of such a characteristic form as an *Echinosphærites* even permits the identification of the exact horizon of the red limestone. It is an equivalent of he *Echinosphærites* limestone of the Baltic provinces. It not only contains the same fossils, but also strongly resembles the latter lithologically. How can we account for such a strange phenomenon as this? We find here a fauna under 22° northern latitude which is precisely the same as that found in the Baltic provinces (59° to 66° N. Lat.), whilst the Silurian fauna of the Himalayas approaches much closer to the Silurians of Central Europe. The fauna of the lower Silurians of the Himalayas is as different from that of the Shan hills as is the Silurian fauna of Bohemia from that of England. It must therefore be assumed that a branch of the Arctic province of the ocean by which the lower Silurian beds were deposited, reached at least to 22° N. Lat. of the Indo-Chinese peninsula; it is even likely that it extended still further to the south, as the limestone beds of the Shan hills are again met with in Tenasserim."

PALÆONTOLOGICAL.—I have glady recorded this discovery by Dr. Noetling, even though it be only one point of advance in our now slow geological progress; because in the present almost exclusive devotion of the service to economic research, palæontological investigation in India is becoming practically extinct, except for that help which is still so graciously accorded by palæontologists in Europe. This is a most regrettable, and even deplorable blot on our hitherto fair escutcheon among those of every Government Geological Survey in the world. Our exchanges from the State Surveys of America, Australia, Austria, Canada, Germany, France, and Russia, show a blazing record of pure geological and palæontological work, to which we can only respond by a fitful spark of chance discovery, or by the pleasanter glow of outside collaboration. We cannot always look for, or depend on, the gratuitous study and description of our unexamined stores of fossils from the Himalayas and Western India; on a portion of the last of which, however, even in his failing health, our untiring and revered friend, Dr. P. Martin Duncan, has only lately volunteered to devote himself as his, perhaps, last contribution to our Indian survey literature.

Dr. Waagen continues at the preparation and description of the Salt Range fossils for the Palæontologia Indica: a fasciculus (Part 2, Vol. IV, Geological Results) is about to be issued.

Professor P. M. Duncan, and our former colleague, Mr. R. Lydekker, have contributed papers to the just completed volume of the Records.

HEAD QUARTERS, CALCUTTA.—Mr. Griesbach was in office until the end of October, preparing his long delayed Memoir on the Geology of the Central Himalayas, in connection with which he did all the remaining plates and text illustrations himself. This Memoir is now passed for press, and will be issued shortly. In the absence of the Director, on tour, from the 1st March to 19th May, and from the 4th August to 4th October, Mr. Griesbach was in charge of the office. He also prepared a paper (Confidential) for the Foreign Department.

He left Calcutta, early in November, for the N. W. Frontier, with a view to extending our knowledge of coal and oil; but has since been attached as Geologist to the Miranzai Expedition.

Mr. La Touche reached Rangoon after his leaving the Lushai column of the Chin-Lushai Expedition, too late in the recess to take up any special investigation in Burma proper. He thererore returned to Head Quarters to close up arrears prior to taking privilege leave. On his return from the latter, in which he was allowed a short extension for visiting tin mines in Cornwall, he was deputed to the boring and pit exploitation of the Daltongunge coal field.

Mr. P. N. Datta was fully, and very advantageously, engaged in compilation at Calcutta during the recess; he has now been placed in Assam for coal exploration in the Tura district, Garo Hills.

MUSEUM AND LABORATORY.—The efficiency of these sections of the Department was well kept up by Mr. Lake, who took over charge of the Officiating Curatorship on the death of Mr. Jones. He was succeeded in October last by Mr. T. H. Holland, who had been selected by Her Majesty's Secretary of State for India, for appointment to the Survey, and who seems eminently and specially fitted for the post by his career in the Royal College of Science, London, and as Berkeley Fellow of Owen's College, Manchester.

SURVEY PUBLICATIONS.—During the year the usual volume of the "Records," consisting of 23 papers, has been issued: of these twelve bear on industrial or economic subjects. Vol. XXIII also contains the second part (Madras and the North-West Provinces) of the Provisional Index of the Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in the Indian Empire, which has been much sought after. A complete and detailed Index to all the papers published in the first 20 volumes of the Records has been prepared during the past year; this is now in the hands of the printer and will shortly be issued.

One memoir was published, forming part 2 of Volume XXIV. In this, Mr. Middlemiss has contributed much new and valuable research on the Physical

Geology of the Sub-Himalaya of Garhwal and Kumaun, which, as evidenced by its reception among geologists in Europe, has proved a welcome addition to the literature of Himalayan geology.

Owing to the continued deputation of our Palæontologist in Burma, only one part (Series XIII, Vol. IV, pt. 1) of the Palæontologia Indica has been published during the year, and that by Dr. Waagen. Part 2 of the same volume will be issued almost immediately.

The remarkable and intense phase of speculation arising out of a sudden development of interest in the auriferous conditions of the Chota Nagpore province, has not proved without its effect on those publications of the Survey which contain even the least reference to the geology of that region. As a consequence, Vol. XVIII, Part 2 of the Memoirs, and several parts of the volumes of the Records are now out of print.

LIBRARY.—The additions to the Library during the past year amounted to 1,593 volumes, or parts of volumes, of which 1,074 were acquired by presentation, and 519 by purchase. Several Geological Maps of portions of Europe were also presented. The Library is in good order, but the want of more accommodation is much felt: it has been more largely utilized this year by visitors and borrowers than at any previous period.

WILL. KING,
Director, Geological Survey of India.

January 31st, 1891.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India, during the year 1890.

ADELAIDE.—Royal Society of South Australia.
ALBANY.—New York State Museum.
ALLAHABAD.—North-Western Provinces and Oudh Provincial Museum.
BALLARAT.—School of Mines.
BALTIMORE.—John Hopkins University.
BASEL.—Natural History Society.
BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
„ Königlich Preussische Geologische Landesanstalt.
„ Royal Prussian Academy of Science.
BOLOGNA.—Royal Academy of Sciences.
BOMBAY.—Marine Survey of India.
„ Meteorological Department.
„ Natural History Society.
BORDEAUX.—Linnean Society of Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
„ Society of Natural History.
BRESLAU.—Silesian Society.
BRISBANE.—Queensland Branch, Royal Geographical Society of Australasia.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Royal Geographical Society of Belgium.
„ Royal Malacological Society of Belgium.
BUCAREST.—Bureau Géologique Roumain.
BUDAPEST.—Hungarian National Museum.
„ Royal Hungarian Geological Institute.
BUENOS AIRES.—National Academy of Sciences, Cordoba.
CAEN.—Linnean Society of Normandy.
CALCUTTA.—Agricultural and Horticultural Society.
„ Archæological Survey.
„ Asiatic Society of Bengal.
„ Editor, "The Indian Engineer."
„ „ "Indian Engineering."
„ Indian Association for the Cultivation of Science.
„ Indian Museum.
„ Meteorological Department, Government of India.
„ Royal Botanical Gardens.
„ Survey of India.
CAMBRIDGE.—Philosophical Society.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy
CASSEL.—Natural History Society.
CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition

CINCINNATI.—Society of Natural History.
COPENHAGEN —Royal Danish Academy.
DIJON.—Academy of Sciences.
DRESDEN.—Isis Society.
DUBLIN.—Royal Dublin Society.
EDINBURGH.—Geological Society.
„ Royal Scottish Society of Arts.
„ Royal Society.
„ Scottish Geographical Society.
GENEVA.—Société de Physique.
GLASGOW.—Glasgow University.
„ Philosophical Society.
GOTHA.—Editor, "Petermann's Geographische Mittheilungen."
GÖTTINGEN.—Royal Society.
HALLE.—Kais. Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.
HARRISBURG.—Geological Survey of Pennsylvania.
HOBART.—Royal Society of Tasmania.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft
LAUSANNE.—Vaudois Society of Natural Sciences.
LEIDEN.—École Polytechnique de Delft.
„ Leiden University.
LEIPZIG.—Geographical Society.
LIÉGE.—Geological Society of Belgium.
LISBON —Geological Survey of Portugal.
LIVERPOOL.—Literary and Philosophical Society.
LONDON.—Geological Society.
„ Iron and Steel Institute.
„ Linnean Society of London.
„ Royal Geographical Society.
„ Royal Institute of Great Britain.
„ Royal Society.
„ Society of Arts.
„ Zoological Society.
MADRAS.—Government Central Museum.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
MELBOURNE.—Department of Mines and Water Supply, Victoria.
„ Geological Society of Australasia.
„ Royal Society of Victoria.
MINNEAPOLIS.—Minnesota Academy of Natural Sciences.
MONTREAL.—Geological and Natural History Survey of Canada.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Royal Bavarian Academy.
NAPLES.—Royal Academy of Science.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.

NEW HAVEN.—The Editors of the "American Journal of Science."
NEW YORK.—Academy of Sciences.
PARIS.—Geographical Society.
,, Geological Society of France.
,, Geological Survey of France.
,, Institute of France.
,, Mining Department.
,, Ministère des Travaux Publics.
,, Société Académique Indo-Chinoise de France.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
,, American Philosophical Society.
,, Franklin Institute.
,, Wagner Free Institute.
PISA.—Society of Natural Sciences, Tuscany.
RIO DE JANEIRO.—Imperial Observatory.
ROME.—Geological Survey of Italy.
,, Royal Academy.
,, Royal Geological Commission of Italy.
SACRAMENTO.—California State Mining Bureau.
SAINT PETERSBURG.—Geological Commission of the Russian Empire.
,, Imperial Academy of Sciences.
SALEM.—American Association for the Advancement of Science.
,, Essex Institute.
SAN FRANCISCO.—Californian Academy of Sciences.
SHANGHAI.—China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
S. PAULO.—Geographical and Geological Commission.
STOCKHOLM.—Geological Survey of Sweden.
,, Royal Swedish Academy.
SYDNEY.—Australian Museum.
,, Department of Mines, New South Wales.
,, Geological Survey of New South Wales.
,, Linnean Society of New South Wales.
,, Royal Society of New South Wales.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VENICE.—Royal Institute of Science.
VIENNA.—Imperial Geological Institute.
,, Imperial Natural History Museum.
,, Royal Academy of Science.
WASHINGTON.—National Academy of Sciences.
,, Smithsonian Institution.
,, United States Department of Agriculture.
,, United States Geological Survey.
,, United States Mint.
,, United States National Museum.

WELLINGTON.—Colonial Museum and Geological Survey of New Zealand.
„ Department of Mines, New Zealand.
„ New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ German Naturalists' Society.
„ Seismological Society of Japan.
YORK.—Yorkshire Philosophical Society.
ZURICH.—Natural History Society.

The Governments of Bengal, Bombay, India, Madras, Mysore, and Punjab.

The Chief Commissioners of Assam, Burma, and Central Provinces. The Resident at Hyderabad.

Notes on the Geology *of the* Salt Range *of the* Panjab, *with a re-considered theory of the* Origin *and* Age *of the* Salt Marl; *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.* (With five plates.)

Introduction.

The Salt Range, since it was first explored in the interests of science, has at several times received a large share of attention at the hands of Indian geologists. In this there is scarcely any room for surprise, owing to its contained mineral and fossil wealth, and to the manner in which the formations are exposed to view. Denudation has used a keen and shrewd scalpel in laying open the anatomy of the rocks in a banding of brilliant rock colours, which there is scarcely any vegetation to hide, or cultivation to disfigure. The inhospitable hillsides, the steeply-carved ravines, and stony wildernesses, though barren and unattractive to the ordinary eye, make up a land of plenty to the geologist the like of which is to be seen nowhere else in India.

So wonderful and vivid, indeed, is the impression made on the mind by a first visit to this region that it will ever be for me an education in itself. Where else in India, or in the world perhaps, can each formation be followed by the eye in its broader lines by its distinctive colour, over hill and hollow, over plateau and ravine, when the range is viewed on a clear day from some commanding height? Where else can be seen a body of horizontal strata comprising members of the Palæozoic, Mesozoic, and Cainozoic groups, lying one above the other in a single cliff section, and apparently as unbroken by great unconformabilities, or by volcanic intrusions, as if they had just been formed? Where else does the geological record, from Cambrian times upwards, present us with a set of rocks unaltered by metamorphism, undisfigured by chemical or dynamical changes, as free in fact from the dust of time as an uncut volume fresh from the binder's hands?

No wonder, then, that the Salt Range, since the appearance of Mr. Wynne's memoir, and during the periodical publication of Dr. Waagen's results in the Palæontologia Indica, has been full of interest for geologists. But, more than all perhaps, the stimulus of controversy has been the agent during the last few years in keeping the interest alive. Dr. Warth, who until recently had been intermittently adding fresh items to our knowledge of the range during holiday rambles undertaken for love, has thrown fresh light here and there into dark places, modified pre-existing results, and necessitated a further examination of the area by the Geological Survey. In 1888 he was successful in finding the first fragments of trilobites that India has yet yielded. Dr. King and myself paid a brief visit to the range in the following spring, when it was determined that I should, in the ensuing cold weather, undertake a thorough overhauling of the subject by the light of the numerous recent discoveries. Another reason urging this course of action was that we saw indications pointing to a theory concerning the origin and age of the Salt Marl entirely different from that which has been hitherto received on the authority of Mr. Wynne. It will be seen to embrace ideas current before the latter undertook his exploration of the country.

Accordingly, in November 1889, I proceeded to take up the work there, assisted by Mr. P. N. Datta, of the Geological Survey.

The Conularia Bed.

Our attention was first turned to the consideration of the Conulariæ-bearing bed. The history of the discovery of the Conulariæ is well set forth in Mr. Medlicott's Annual Report for 1885 (Records, Geological Survey of India, Vol. XIX, Pt. 1), and in Dr. Waagen's note on the subject in the same number.

These fossils were first found by Dr. Warth, and thought by him to be ordinary pebbles, and therefore of derived origin. Later, he came to the conclusion that they were concretions *in situ* in the rock, a point of extreme importance at that time, if true, as it altered the age of the lower part of the Olive Series, including the underlying Boulder-bed, from about Cretaceous to Palæozoic.

Mr. R. D. Oldham's subsequent brief visit to the Salt Range once more plunged the matter into obscurity by his decision that they were true pebbles, though probably derived from a concretionary bed, and that, therefore, in their present position, they were of no use in determining the age of the stratum in which they were included (Records, Geological Survey of India, Vol XIX, Pt. 2). In this decision Mr. Medlicott did not entirely agree, as expressed in a note following the one by Mr. Oldham quoted above.

This was the state of the case as regards the opinions for the derived, or *in situ* nature of the Conulariæ when Dr. King and I arrived on the ground, except that we had later observations made by Dr. Warth to the effect that the Boulder-bed and Conularia-bed had been found continuous beneath the Speckled Sandstone, and therefore that they were older than the Productus Limestone. Our impressions as to the Conulariæ which we gathered during the short time at our disposal agreed pretty well with those of Mr. Oldham. We found, however, a fossiliferous zone of large bivalve casts between the base of the Boulder-bed and the Conularia zone in the neighbourhood of Dandot, which, if the fossils are sufficiently well preserved and characteristic, should settle the age of the beds irrespective of the Conulariæ.

From a recent paper in the Records (Vol. XXIII, Pt. 1) by Dr. Waagen, it would appear that a bed of the same horizon had been previously found and collected from; and owing to the mistaken identity of the badly preserved casts, had been temporarily regarded as Upper Cretaceous [1]; but that on later examination by him in the light of Dr. Warth's discoveries, some of them were found identical with certain Australian Carboniferous species.

During the cold weather Mr. Datta and myself were able to see a good deal of the Conularia-bed, and the results of numerous examinations of different parts of the range, where the Olive beds are exposed, are here given briefly—

(1) Many of the Conularia concretions show a rolled and abraded surface, with truncations of the fossils, as described by Mr. Oldham.

(2) Near Makrach the Conulariæ, on the other hand, are very characteristic nodules in shape and figure. They are frequently elongated, pear-shaped, or irregular aggregations.

(3) In the neighbourhood of Choya-Saidan-Shah nearly all the so-called pebbles are not perfectly smooth as to their surface. They are dotted or pitted all over with small marks, which, examined carefully, may be seen to be nothing else than the impressions of grains of coarse sand. This indicates

[1] The fossils have not yet been studied in detail by Dr. Waagen.

that at the time of their incorporation with the sandstone they were soft enough to take on the impressions of the sand grains: that they were, in fact, soft clay or marl balls.

(4) At Chel hill, and north-north-west of Khusak, immediately beneath the Conularia pebble zone, there is a layer of soft sandstone with small patches of grey calcareous claystone or marlstone. These patches could not be separated from the rock, and were certainly not pebbles. In, about, and among these patches were Conulariæ and bivalves. Conulariæ were also found in the sandstone.

(5) Just behind the village of Raturcha the Conularia layer is very suggestive of an origin by concretionary action. There is a concretionary-tabular layer of hard, grey marlstone, that is to say, a layer in which the concretions are not separated from one another. Tracing this along in different directions, it soon splits up into free concretions containing Conulariæ. The whole was clearly one band, but free concretions appeared to have formed only when a Conularia or other fossil was present as a nucleus.

The conclusions from these observations seem to be that the Conulariæ are approximately contemporaneous with the stratum in which they are found; that they lived and died on a sandy and marly sea bottom; that after death, marl or calcareous clay collected round them; that after this, whilst still soft, they were in many cases rolled about as clay balls receiving a coating of sand, and then buried in the overlying deposits. The Conulariæ thus become a true index as to the age of the beds in which they are found, which, together with the Boulder-bed, must be regarded as Palæozoic.

Dr. Warth (Records, Geological Survey of India, Vol. XX, Pt. 2) describes a locality in the Nilawan ravine where the Boulder-bed, underlying the Speckled Sandstone of Wynne, includes Conulariæ. In addition to the above, we were fortunate enough to find the Boulder-bed and Conularia-bed in normal appearance and sequence underlying the Speckled Sandstone at the following localities:—(1) A little west of Makrach; (2) Makrach valley, east of Dilwal; (3) on both sides and at the north end of the Sardi glen. As the Speckled Sandstone is older than the Productus Limestone, the cumulative evidence in favour of the Boulder-bed and at least part of the Olive series being Palæozoic is irresistible.

Aspect of the Boulder-bed, Olive Series, and Speckled Sandstone.

Besides the Conularia-bed, our attention was very early attracted to the remarkable aspect of the Crystalline-boulder bed, the whole of the Olive series and Speckled Sandstone, and their inter-relations. Mr. R. D. Oldham (Records, Geological Survey of India, Vol. XIX, Pt. 2) was the first to detect the aspect of unconformability between the basal portion of the Boulder-bed and the Salt-pseudomorph zone near Pid pole—an observation which may stand good in spite of the Palæozoic age of the Boulder-bed and Conularia zone. The following is the additional evidence we were able to obtain in support of this unconformability:—

(1) In making a collection of facetted and striated rocks included in the Boulder-bed, and also a typical petrological collection of the crystalline boulders, we frequently came upon largeblocks and included masses of

the Salt-pseudomorph rock surrounded on all sides by the matrix of the Boulder-bed; whilst about one and a half miles north by west from Khusak Fort I obtained two rather large boulders, one of Purple Sandstone and one of Magnesian Sandstone, both grooved and scratched after the manner of glaciated boulders. On the west side of the Sardi glen, a little north of Sardi, there is a local development of the Boulder-bed, 40 feet thick, with Conularia bed above, made up of huge fragments (a foot or more across) of the Magnesian Sandstone, with a few crystalline boulders.

(2) West of Makrach the Boulder-bed oversteps the Salt-pseudomorph zone, and becomes directly superposed on the Magnesian Sandstone. Further west, in the neighbourhood of Malot and Sardi, the Magnesian Sandstone becomes gradually overstepped in the same way, until in the glen south of Nurpur the Boulder-bed rests on the Obolus zone (the latter being well recognized in all its facies, *e.g.* lumpy purple shales, with worm tracks or fucoid marks, micaceous, and glauconitic, &c.). In the Amb glen and neighbourhood, the Boulder-bed which still forms the base of the Speckled Sandstone is in contact sometimes with the Purple Sandstone and sometimes with the Red Marl.

Since Dr. Warth's discovery in the Nilawan that the Boulder-bed there was the same as the Boulder-bed in the more eastern parts, it had of course been assumed that the different Boulder-beds deemed to be distinct by Wynne were one and the same, and marked a line of unconformability or overlap running the whole length of the Salt Range. Hence evidence under head (2) is merely confirmatory of what has been conjectured by Dr. Waagen (*see* Pal. Ind., Geological Results, pp. 47-48).

It being understood, therefore, as proved that the Boulder-bed, Olive series, and Speckled Sandstone form one series unconformably overlying the subjacent rocks, I will now proceed to mention a few facts that we were able to glean with regard to them, and to give one or two vertical sections and sketch sections through the series at different points of the range.

First, with regard to the facetted, striated, scratched, and polished crystalline pebbles found in the Boulder-bed, although there has been some controversy on the subject,[1] I am able to state that, after a large acquaintance with the boulder clays of the eastern parts of England, I can detect no essential difference between them and the Boulder-bed of the Salt Range, except that the latter has lost its clayey consistency and become a dark shale, sandy shale, or sandstone, as the case may be. The similarity is not a strained resemblance, but a complete similarity, carried out in every detail as to shape, size, sub-angularity, and scratching of the pebbles, and their condition merged in and completely surrounded by the finer matrix. The character of the boulders, consisting, as they do, of crystalline rocks (chiefly granites, micro-granulites, felsites, schists and quartzites) is very unique, owing to the complete absence of crystalline and igneous rocks in the Salt Range as rock masses with the single exception of the Khewra trap. I hope at another time to give a microscopical description of slices taken from fourteen typical boulders.

Vertical Section No. 1, Plate I, is taken through the Boulder-bed and Olive series, a little west of Pid pole. It explains itself.

[1] Referred to by Mr. R. D. Oldham, Records, Geological Survey of India, Vol. XXI, p. 160.

Horizontal Sketch Section No. 1, Plate II, is taken across the valley west by south from Raturcha, and shows a 30-feet bed of reddish, speckled, fine sandstone, which already in this eastern part of the range begins to foreshadow the ultimate large development of the Speckled Sandstone.

Horizontal Sketch Section No. 2, Plate II, is taken across the Makrach valley east of Dilwal, and illustrates, among other things, the first in-coming of recognizable Speckled Sandstone above the Olive Series.

Vertical Section No. 2, Plate I, is taken at the head of the glen above Sardi, and shows the Speckled Sandstone as having now attained a marked thickness, slightly exceeding that of the Olive series. As the section on the east side of the head of the glen observed by us differs in some important respects from that given originally by Mr. Wynne in his memoir (Memoirs, Geological Survey of India, Vol. XIV, p. 180), I extract the following from my note-book:—"The Salt Marl and Purple Sandstone are in their normal positions, though the former is not seen in this part of the glen but lower down. Above the Purple Sandstone we found that the shales, marked by Mr. Wynne on his map as Silurian, undoubtedly belonged to the Obolus beds, for there were the same characteristic purplish, lumpy shales with worm (?) or fucoid markings, glauconite grains, and mica flakes. We found the B zone (for explanation see on) with some specimens of *Hyolithes wynnei*. Above that we got the Magnesian Sandstone in normal order, apparently superposed conformably. After a fair thickness of this, though thinner than at Khusak fort, we came upon the Boulder-bed, of small thickness, but perfectly recognizable, being formed of crystalline boulders of rather small size in a dark shaly matrix. Next above this, in some olive sandstone, came the Conularia-bed, as recognizable as before, and above this a normal section in the Olive series for some way, until it gradually merged into the Speckled Sandstone. The latter is fine-grained in its lower parts, but the grains of sand are always angular or sub-angular. In its upper part it becomes very coarse-grained and conglomeratic. The pebbles are angular or sub-angular, and composed, the smaller ones chiefly of vein-quartz and a compact felsite, or some allied rock, the colour being light red. The larger pebbles, which generally average 1 to 2 inches across, are chiefly composed of the compact red felsite. There are also sundry pebbles of a limestone, or calcareous sandstone, resembling the Magnesian Sandstone, and others of dark quartzite. In this conglomerate there are none of those coarsely crystallins red granites so common in the Boulder-bed. Above these slightly conglomeratic beds come some chocolate-coloured shales, or hardened clays, alternating with coarse sandstones not conglomeratic at all. In the uppermost parts of these beds there are some few shales of a paler tint, which may perhaps be called lavender. The section then becomes obscured by talus from the nummulitic scarp."

It will be noticed that Mr. Wynne, in his section referred to above, does not acknowledge identifying either the Obolus Shales or the Boulder-bed. His black shale band No. 3 he by inference regarded as the representative of the Obolus Shales, though he does not say so. At page 92, however, he mentions generally that the "lower part of the group [Speckled Sandstone] is often seen to consist of brownish and light-coloured sandstones with some whitish flags and dark shales as well as bands of conglomerate, the pebbles in which are of granite, syenite, and other crystalline trappean or metamorphic rocks, this portion having a general resemblance to some beds of No. 10" [*i.e.* the Boulder-bed and Olive series]. Considering the wonderful accuracy of most of Mr. Wynne's work in the Salt Range and elsewhere, his failure to see more than a general resemblance between the two is difficult to understand.

Vertical Section No. 3, Plate I, is of the cliffs east-north-east from Bhal, east pole; Nurpur. In this the Boulder-bed is observed resting directly on the Obolus beds, that is to say, the Magnesian Sandstone is absent. The Olive series is very thin, and the Speckled Sandstone fully developed. I have indicated, by different methods of shading, the remarkable colour banding of this section,—a character pervading all the sections in the Salt Range, and giving to them such a realistic appearance from the geologists' point of view.

The Obolus Shales.

One of the principal objects of our presence in the Salt Range was to verify the find of trilobites made by Dr. Warth. The account of this find is given by Dr. King in the Records (Vol. XXII, Part. 3). The very small fragments, three in number, were identified by Dr. Waagen as belonging to the genera *Conocephalites* and *Olenus*. I never saw the specimens myself, and as Dr. Warth was a little uncertain as to the exact locality from which they had come, we had to make a new search in the Obolus beds of Khusak Fort for fresh proof.

After some fruitless efforts we were at length successful, Mr. Datta turning out the first fragment on the cliffs north of the Khusak fort hill from a dark purple, calcareous, shaly band (zone B), very firm within, and ringing under the hammer. Numerous specimens of *Hyolithes wynnei*, and of small brachiopods, were also obtained. After one or two more fragments had been found, we transferred our attention to the Fort hill itself. At a point on the east side, where a natural gallery runs round the base of the Magnesian Sandstone cliff, I found a finely laminated, hard shale of dark colour, an inspiration to search which resulted in a large collection of some better preserved fragments of trilobites, and numerous small brachiopods. Many of the latter were beautifully preserved in the hard, thin-bedded rock. We then proceeded to work systematically the whole of the section through the Obolus beds, from the top of the Purple Sandstone up to the Magnesian Sandstone.

Many pleasant memories are connected with the days we spent on the slopes round Khusak fort. For the first time in the annals of the Geological Survey two of its members were consciously engaged on Cambrian rocks, unearthing some of the oldest known forms of trilobites. But the chief marvel to me during the many hours a day we spent cramped or blistering on the steep slopes, was that these very ancient fossiliferous rocks should have escaped all the disturbance attending upheaval of the earth's crust during the geological ages, epochs, and eras that have passed over them.

In Plate V I have outlined a view of the hill on which Khusak fort stands. It will serve to give the reader an idea of the style of rock-sculpture, bare of vegetation, so universal in the Salt Range. Its geological structure, stratigraphy, and fossil zones will be understood from the profile view of the same in Plate II, and from the Vertical Sections Nos. 4 and 5 in Plate I.

Infra- and Supra-Nummulitic Rocks.

In one respect this season's work was signally barren in any valuable results. I refer to the examination of the beds immediately underlying the Nummulitic

Limestone. Their position is unfortunate, on account of the tendency of the Nummulitic limestone to spread for a considerable distance in the form of a talus down the slopes below the Nummulitic scarp. This is the one blot in the otherwise perfectly exposed sections of the Salt Range. What the Boulder Clay in many parts of England is, in obscuring the true relation of the rocks below it, so is the Nummulitic limestone of the Salt Range. Its nodular character, which causes it to weather into egg-shaped lumps, is doubtless a great assistance in spreading it far beyond its *in situ* limits into incongruous positions above other formations. Only in a few isolated places has a landslip or watercourse cut away the talus, leaving the rocks visible beneath. Even then, owing to the changeable nature of the deposits, which are shales, marls, and sandstones, lateral continuity is never found, and the correlation of one distant exposure with another is therefore well nigh impossible. I do not think, therefore, that the unorganized mass of local observations that we made in this connection would be worth recording as it is.

Dr. Waagen has given a classified arrangement of these beds in his last memoir (Pal. Ind., Geol. Results, pp. 51, 52); but he truly says that the subject will require much additional study before all the points are cleared up. My own impression is that such obscured sections could only be properly unravelled in the course of many years by the united efforts of a geological field-club.

Turning to the supra-Nummulitic rocks, the junction between them and the Nummulitic Limestone is one presenting some difficulties, and it gave rise to a little friction of opinion between Mr. Medlicott and Mr. Wynne. The chief questions were as to whether the junction between the two was conformable or not, and as to whether the apparent conglomerate at the base of the former was a real or a pseudo-conglomerate. Mr. Wynne, in his memoir on the Salt Range, declared that the two series were conformable, and the conglomerate not a real basal conglomerate, but of the nature of many of those semi-concretionary indurated clay-conglomerates of the Nahan Sandstone, which sometimes contain bone fragments. Mr. Medlicott had previously expressed an opposite opinion (Mem., Geol. Surv. of Ind., Vol. III, p. 91) that the sandstone lay on a denuded surface of nummulitic limestone. But in his Sketch of the Geology of the Panjab, written in 1883-84, though only published in 1888, he seems to have given up the former position, at least as regards the trans-Indus continuation of the Salt Range. He says (pp. 21 & 22): "In the westerly portions of some of these ellipsoids the eocene limestones are closely associated with greenish clays like those in the eocene strata flanking the outer Himalayan hills, and these clay rocks sometimes contain sandy layers rendered conglomeratic by the presence of nummulitic limestone pebbles enclosing nummulites, so that the occurrence of an apparently derived detrital rock of this kind cannot always be taken as evidence of later general age than the rock of which it is formed. Bearing this in mind, it seems not unlikely that the conglomeratic or pebbly layers found at the base of the tertiary beds in the neighbourhood of the Sheik Budin *gund* represent some stage of the eocene period, a surmise that might even be extended to the more heterogeneous detrital accumulations of pre-tertiary rock, fragments of which form the floor of the tertiary series in the northern part of the Kiri Khasor ridge."

To me it seems that the sudden change from a great thickness of nummulite-bearing limestone to a still greater thickness of sandstones, identical in composition with the Nahan Sandstone, is in itself as telling a proof of discontinuity as could be desired in this part of the earth, where marked unconformabilities are absent owing to the fact that the upheaving and crumpling forces have not acted at all until modern geological times. The conditions that brought about the deposition of the limestone, and the entirely different ones that resulted in the Nahans, could only pass into each other thus suddenly by a revolution on the earth's surface, such as the cataclysmists were wont to picture to themselves. I cannot doubt that a break in time must be indicated here, sufficient to allow the one set of conditions to grow out of the other set.

The intervening conglomerate was observed by us in several places. In the neighbourhood of Choya-Ganj-Ali-Shah the conglomerate had nothing whatever "pseudo" about it. We found it to consist of a matrix of slightly hardened sand-rock, containing well-rounded pebbles of Nummulitic Limestone containing nummulites.

Associated with these were a very large number of pebbles of a limestone very similar to the Nummulitic Limestone, but of an ochre tint outside and destitute of fossils. There were also found a number of pebbles of crystalline rocks, some of them not unlike the red granite of the Boulder-bed. The presence of the crystalline pebbles is itself a point of very suggestive meaning, for these same pebbles in the Boulder-bed, as we now know, form the base of a distinctly unconformable series. Another feature observed by us was, that, while in every case the conglomerate passed upwards into the normal Nahan Sandstone, it did not always lie directly on the Nummulitic Limestone. Near Choya-Ganj-Ali-Shah there is a small intervening thickness of finely laminated purplish and olive-grey shales that reminded me at once of the Sabathu nummulitic shales of Garhwal. Their appearance was quite distinct from the reddish purple shales inter-bedded with the Nahan Sandstone.

Half a mile south of Kallar-Kahar on the Sardi road, a good junction section is exposed. On the top of the Nummulitic Limestone there is first a thin layer of purple shale, then a conglomerate containing numerous rolled pebbles of Nummulitic Limestone in a coarse sandy matrix. Above this are 1 or 2 feet of calcareous grit, and then normal Nahan Sandstone, though rather soft.

Dr. Waagen, in his Geological Results, equally comes to a similar conclusion, by indirect reasoning from the Indus river section. He writes (p. 24): "The chief results which we can deduce from this description of the section consist in the fact that on the whole the succession of the beds is not dissimilar to that established in the Simla region; and that on the Salt Range side of the Potwar plateau there exists a great gap in the tertiary strata, only the lowest (Nummulitic) and the highest (Siwalik) beds being there represented."

ORIGIN AND AGE OF THE SALT MARL.

Apology for imperfect treatment of the subject.

I now come to the difficult part of this paper, namely, the setting forth of sundry reasons for the doubts I have felt with regard to the received explanation of the origin and age of the Salt Marl, or Red Marl, and its contained minerals. It is always a thankless task to indulge in destructive criticism, more especially in a case such as the present, where I cannot carry my demonstration beyond the range of probability into the sphere of certainty.

Owing to the restrictions now imposed on the Geological Survey, in consequence of a greater demand for positive knowledge regarding the economical resources of India, it has become impossible to give continued attention to any one subject in any one area of the empire. Change is the order of the day, and our visits to a place must be brief. and come to an end generally when the particular question, whether relating to coal, oil, or what not has been disposed of. The system of local head-quarters away from library, museum, and laboratory during the hot and rainy months of the year is also a serious handicap to complete scientific research. I must therefore content myself with a summary discussion of my field notes, merely pointing out in what direction I think conjecture lies, touching the deeper problems involved.

Peculiarities in the structure and lie of the Salt Marl.

On reading Mr. Wynne's memoir, and before arriving at the Salt Range, I was much struck by certain peculiarities which the Salt Marl presented, as described by the author. At that time I drew up the following list of these peculiarities, and (as it seemed to me) inconsistencies:—

(1) Its soft and homogeneous nature, for the basal rock of the range of Lower Cambrian age at least.
(2) The absence of definite stratification in it.
(3) The abnormal mode of its occurrence mixed up with different formations, which Mr. Wynne accounted for by very extraordinary faults.
(4) The presence, on the other side of the Indus, of important salt-bearing beds separated from the Salt Range by a short distance only and yet supposed to be of very much younger age, namely, doubtfully eocene.

The suspicion taking shape in my mind at that time was that the Salt Marl, instead of constituting the foundation on which rest all the other formations of the range, might be of much more recent age, and formed otherwise than by evaporation and desiccation of salt lakes, such as that of Utah, or of inland seas like the Dead Sea and the Caspian.

Division of the subject.

In putting forward the present theory as to the origin and age of the Red Marl, I shall deal with the subject under the following three heads: (1) Structure and composition of the Red Marl; (2) its distribution and connection with other formations; (3) concluding hypothesis.

(1) *Structure and Composition of the Red Marl.*

Mr. Wynne's description.

The Red Marl, with its immense masses of rock salt and gypsum, has been very thoroughly described by Mr. Wynne in his memoir, pages 70-84. I shall cull a few of his paragraphs as being of special interest, or as bearing on the present theory. Of the Red Marl itself, he gives Dr. Fleming's remarks on its chemical composition, which run as follows:—

"It does not disintegrate when treated with hydrochloric acid, but in powder effervesces strongly, the greater part remaining undissolved as a red mud, composed of clay and sulphate of lime; the portion soluble in acid consists of carbonate of lime and carbonate of magnesia in about equal proportions with a little alumina and peroxide of iron, to which it owes its colour."

Mr. Wynne concludes from the above that the term "gypseous marl" is not inapplicable. As to its petrological nature and aspect he writes—

"The marl forms the most noticeable portion of the saline group, but in close association with it are thick beds of gypsum and thicker ones of rock salt. It is tough rather than hard, but when very dry, possesses much the consistence of sun-dried brick."

He further writes—

"Beyond the gypseous, saline, and dolomitic layers the red marl bears few original traces of stratification, or inter-stratification, generally none at all; hence it is difficult to form any correct idea of its thickness. * * * * It may be doubted whether another example could be found of such a homogeneous, argillaceous and aqueous deposit of the same depth in which signs of stratification are equally absent. In strong contrast to this is the perfect lamination frequently seen in the enclosed salt, and in the platy dolomitic layers. From the contorted state of the latter and the curvature of the beds of salt in some of the mines, it may be presumed that, whether stratified or not, the salt marl is likewise disturbed."

No divisional planes.

It is necessary to emphasize some of the points quoted above. So far as I have seen, I should say that the Red Marl, except when it encloses masses of the dolomitic rock, or when it is in combination with beds of gypsum and rock salt, *never* shows any stratification whatever; nor is there the slightest trace of any divisional planes in it. On taking a lump in the hand, the broken edges are precisely such as one would get in any structureless, amorphous mass. The likeness to a sun-dried brick mentioned by Mr. Wynne applies as much in the matter of homogeneity as in hardness. Seen in large masses on the hillsides, it equally displays a lack of structural planes. In this respect it differs from limestone and other similar, chemically formed rocks; for a compact amorphous limestone, though evincing but little trace of stratification in the hand specimen, very often gives to the surface of the earth either a scarp, cliff, or moulded slope, by which its obscure planes of original deposition can be discerned. But there is no such hint thrown out by the Red Marl. Denudation acts on it as it would on a heap of sand, making streamlets here, and rough hillocks there, the former winding in a capricious manner, and the latter strewing the slopes at random.

No colour banding.

With the absence of divisional planes there is also an absence of colour banding. The Red Marl, though varying somewhat in the brilliancy and depth of its colour, is of one general hue throughout.[1] There is no parallel system of tints, such as the colour banding of slates (which reveals the original stratification of the slates, although the power to split along it has been taken away).

Not a sedimentary rock, but a chemical production.

Again, the Red Marl in itself, that is to say without reference to the dolomitic layers of which I shall have to speak anon, is not a clastic, nor even a sedimentary rock, but a chemical production. There are no grains of sand in it, no pebbles of foreign rocks—nothing to indicate that it ever grew layer by layer and stratum by stratum, like a sub-aërial aqueous deposit.

The absence of all organic remains in it also points in the same direction.

Even the lenticular patches and layers, and the massive amorphous beds of gypsum, as well as those of the rock salt which are said to be bedded, stand on a

[1] With the exception of certain pale greenish-grey blotches, which will be referred to presently.

very different platform to the sandstones and shales which are interbedded with the salt-bearing marls of England and Germany. These gypsum and salt layers are not necessarily strata, in the sense of having been *deposited layer above layer*. They may only be beds in the sense that the folia of a gneiss, the different flows of a lava, or the mineral layers of a vein or lode, are beds.

Summary.

In short, to sum up, there is no evidence derived from the structure and composition of the rock itself that it had a sub-aërial, as distinguished from a subterranean, origin. The belief therefore that it was formed after the manner of an aqueous deposit in an inland sea or a deep ocean is, at the very outset, an *assumption* with no strictly analogous case to go upon.

Positive evidence.

Turning from the negative to the positive aspect of the question, I have some new facts to bring forward now regarding the inter-relations between the dolomitic layers and the Red Marl on the one hand, and the dolomitic layers and the gypsum on the other.

Absorption of the dolomite rock by the Red Marl.

At Kavhad there is a good exposure of the Red Marl showing the following peculiarities:—(1) Its brick-red colour and homogeneous aspect is broken by a net-work or sponge-work of filmy, anastomosing strings of gypsum; (2) The pale grey dolomite involved in the Red Marl is not disposed in continuous beds but in vesicular, or honey-combed lumps, of irregular shape and size; (3) The bright red matrix, if examined carefully, is seen to be dotted all over with pale greenish-grey patches. Some of these are as large as an inch across, but most of them are mere specks. It is noticeable, however, that these specks are drawn out like the sputtering of a pen, and that in their course through the rock they keep very generally a more or less parallel direction for a short distance, but waving about. They give an irregular streaky and patchy appearance to the marl, as if the former had been kneaded up with the latter, just as patches of white bread are sometimes found incorporated by mistake in a loaf of whole meal flour. But the most important point in connection with these grey specks is that they may be traced by every gradational form into disintegrated patches of the honey-combed dolomite. The latter, in its larger pieces, is as distinct from the marly matrix as an included fragment of schist often may be in a granite; but as these lumps become more honey-combed, and more vesicular, they split into groups of three or more straggling and corroded[1] remnants of dolomite, and these again into clusters showing a gradual change into the greenish-grey specks previously mentioned. In the latter condition they are one with the Red Marl. The Red Marl in fact seems to have devoured the dolomite, to have absorbed or digested it, just as a pot of molten lead absorbs the solid bits thrown into it. Of course the actual process of the transformation described above is not seen, but only the various stages which I have thus vivified for facility of description.

Passage of beds of dolomite into gypsum.

A parallel change from the dolomite into gypsum is also indicated by numberless passage forms at a great many places in the Salt Range. Two miles north of Buri Khel there is a good example. The dolomite, roughly bedded in some places, solid in its central portions, but crumbling and honey-combed at the edges, occupies areas of many

[1] I use the verb "to corrode" here in a general sense for want of a better word.

square yards among the gypsum and Red Marl. The smaller patches of the dolomite exhibit the following stages of change:—(1) The hard flinty-looking rock becomes dotted with minute punctures, either in rows or nebulous patches. These holes are as fine as a pin-point. (2) In the near neighbourhood another lump of dolomite may be taken in which there are larger ragged holes, such as appear in a moth-eaten garment. Close examination shows that these larger holes are bordered by the minute punctures, and indicate that the former were made by the close approximation and fusion of the latter. (3) Joining these larger ragged holes there run canals sometimes roughly following joint planes in the dolomite. (4) Another stage of change may be seen by the dolomite assuming a honey-combed structure, somewhat resembling pumice, in which the holes are larger than before. At the same time the joint planes at right angles to one another are converted into widened fissures cutting up the lump into irregular cubes and masses, gypsum taking the place of the dolomite along the cracks and holes. (5) Groups and strings and lumps of the dolomite in the final stages are honey-combed to a spongy and then to a reticulate fibrous texture, the holes and meshes being occupied by gypsum.

I take it as beyond dispute that the one rock has gradually replaced the other original rock, probably by some metamorphic[1] change that finds a parallel in the well known example of laterite formed from gneiss. It would thus seem that, according to circumstances, a genuine stratified deposit of dolomite has been converted, either into a pure gypsum, or into a less pure gypseous marl.

(2) *Distribution of the Red Marl and its Relations to the other Formations of the Range.*

Importance of its apparent stratigraphical position.

Having found that the Red Marl shows no traces in its composition and structure of a sub-aërial detrital origin, but that, on the contrary, it does show signs of a very different mode of origin by some form of rock change, I will now proceed to attack the question from a different standpoint. Obviously enough, its *allure* with regard to the other formation sof the range must be vitally important in coming to any more specific conclusion concerning it. If the Red Marl occupied a position such as the salt-bearing marls of the Trias of Europe, between a respectively lower and upper set of stratified detrital rocks and interbedded with them, that position would be immensely more in favour of a detrital origin for it than is the case in reality.

Its ambiguous position at the base of the rock groups.

All who have read Mr. Wynne's book will see that the place assigned to it by him, at the base of the whole of the Salt Range groups, shuts out much of possible proof along that line. As for Dr. Waagen's belief in a Lower Purple Sandstone normally underlying the Salt Marl, I shall have to return to the point again later, merely remarking here that the instances which he brings forward in support of his allegation can be much more simply understood as inversions of the overlying Purple Sandstone.

[1] This word is used in its strictly derivative sense only.

But Mr. Wynne, though unable to find in the range or elsewhere any evidence of what lies beneath the Red Marl, does not appear to have had any misgivings as to the relation of the Red Marl to what comes above it. He states (p. 85) that the Red Marl apparently passes up into the Purple Sandstone. If, therefore, my efforts to show that the marl is not in normal stratified succession beneath the Purple Sandstone are to be successful, I must show this apparent passage to be unreal.

Alleged passage of the Red Marl into the Purple Sandstone.

Now continuous sequence between two formations is best established by the one formation being found *interbedded* with the other. But there is no such continuous sequence as this between the Red Marl and the Purple Sandstone—no alternating layers, first of marl and then of sandstone, dovetailing the two together. The very few isolated and doubtful cases[1] in which some apparent interbedding takes place are justly mentioned with considerable reserve by Mr. Wynne himself. Speaking broadly, there is no interbedding between the two.

Interbedding the best proof of continuous sequence.

The only sense then in which the Red Marl could be said to pass up into the Purple Sandstone would be by the existence of an intervening layer of rock petrologically neither a marl nor a sandstone, but a mixture of the two. And this is what Mr. Wynne relies on to show the above passage. For my own part I could never satisfy myself of such a passage bed indicating continuous sequence. I admit that in nearly every section of the two rocks in contact there is what at first sight might be mistaken for a passage bed, but which I was able to determine at very many places to be of an entirely different nature.

No petrological passage.

The Red Marl, from its proneness to soften at the surface when rain falls upon it and to become in consequence much mixed up with fragments of rocks from the cliffs above, is generally a difficult rock to study. In a country less arid and bare indeed, it would be almost impossible to find a natural section of the rock free from its load of surface *débris*. As it is, there are occasionally exposed reliable junction sections of the Red Marl and Purple Sandstone in close conjunction. In every one of these the layer of rock at the junction is *brecciated*—such a junction in fact as might be understood in a variety of ways *other than* that of the natural deposition of the Purple Sandstone conformably above the Red Marl. I will now detail some sections, which will, I hope, tend to clear up the mystery in part at least.

True nature of the junction of the Red Marl and Purple Sandstone.

The first instance I will give occurs at the north edge of the exposure of Red Marl west of the main road from Khewra to Choya-Saidan-Shah. It is a continuation of the band of Red Marl which crosses the road about two miles north-west of Khewra railway station. On descending into the depths of the little cañons among the masses of white and red rock mixed largely with surface *débris*, we find at the north edge of the marl, where it comes in juxtaposition with the Purple Sandstone, an arrangement as seen in Sketch Section No. 3, Plate III. To the right of the section there is the massive, well-bedded Purple Sandstone, which, as it approaches the marl, becomes

Junction exposure north-west of Khewra.

[1] *See* pp. 228, 229, 230.

much shattered, more like a rock approaching a fold-fault than anything else that I can think of. The masses of the sandstone first keep a rough parallelism, though broken across, shattered, and detached from the consecutive layers of sandstone. Further on, towards the marl, there comes a well-marked layer, 3 or 4 feet across, AA of the section, in which the fragments of Purple Sandstone are smaller, though keeping their angularity and turned about in all directions; the matrix in which they are scattered being a mixture of what appears to be powdered-up portions of the sandstone mixed with Red Marl. This abruptly ceases, and a band of gypsum, G, follows, and then a layer of the pure amorphous Red Marl.

The junction layer AA is an important one to which attention must be drawn. Its internal evidence proves that it was formed subsequent to the contained fragments of Purple Sandstone, which oriented, as they are, in all directions, nevertheless keep their individuality in a most perfect way. We must, I think, conclude that it is of the nature of a breccia, and marks a line of relative movement between the two formations.

Junction exposure north of Khewra.

A similar section up the Khewra glen, where a mass of very pure Red Marl underlies the Purple Sandstone at a much lower angle, presents the same features, there being a distinctly brecciated band a few feet wide separating the sandstone from the marl.

Junction section at Kavhad.

At Kavhad, where the glen bifurcates, there is also a very good exposure of the above rocks in conjunction. This is illustrated in Sketch Section No. 4, Plate III. On the left is good, strong, normal Purple Sandstone, sometimes veined with pale green tints, whilst on the right is bright, scarlet, and sometimes vesicular Red Marl, of a wavy tufaceous aspect, already described (see *ante*). In between the two comes a zone which in the distance often has the appearance of a passage, as stated above. It is two yards across, and is in truth half marl and half purple sandstone, but in this way: the two are not interbedded in the ordinary sense of the term, nor is there a gradual passage from the one rock into the other, but there is a matrix of reddish and greenish marl which is stuck full of fragments of Purple Sandstone, sometimes roughly indicating bedding. Certainly, all the fragments are angular and lie more or less in the direction of the general bedding, but there is no suggestion of a passage from the marl to the sandstone. The appearance in fact is just that of a brecciation of one rock by intrusion of a later one among it. This line of junction can be followed along the glen for some way up stream. I have selected it for description partly on account of the verticality of the beds in a cliff section, which can be trusted as being entirely free from surface re-arrangement.

These three examples may, I think, stand by themselves as sufficient proof of the general statement that I have made, to the effect that there is never any real passage upwards from the Red Marl to the Purple Sandstone.

Further examples, illustrating movement of the Red Marl since the deposition of many of the overlying formations.

I now proceed to offer a series of examples, illustrated by Sketch Sections, showing that the Red Marl must have possessed a plasticity, and a power of movement, subsequent to the deposition of many of the formations above it.

Although it is true that the Red Marl, over the greater part of the area to which it is confined, is generally infraposed with regard to the Purple Sandstone, yet there are so many local exceptions to this rule, which have been noticed by Mr. Wynne, as to make it by no means universal.

One set of exceptions, not regarded by Mr. Wynne, is very remarkable, in that the Red Marl forms the core of an inverted flexure or the line of the middle limb of a sigmaflexure, or the line of tearing or thrust which has followed on the formation of the sigmaflexure.

The Red Marl forms cores of flexures and occupies lines of fracture.

It is strange that Mr. Wynne in his memoir has scarcely mentioned these great inverted flexures, which are sometimes of special prominence on the scarped southern edge of the Salt Range. In some cases, as at Dandot, he has misinterpreted the lie of the rocks, and in others, as the Amb glen, he seems to have ignored the matter.

Seeing that the general structure of the Salt Range is that of a plateau with but few of those gigantic structural features belonging more strictly to lofty mountain ranges, it is a peculiar circumstance that when violent inversions and thrustings have taken place, they should always be associated with the Red Marl.

Inversion south of Dandot.

In Sketch Section No. 5, Plate III, I have represented, in a more or less diagrammatic way, the inversion so prominent on the scarp south of Dandot. It will be seen from the section that the Purple Sandstone is doubled in thickness with a core of gypsum and Red Marl. The whole of the Boulder-bed and Olive series is also repeated in an inverted order and coming immediately below the Purple Sandstone. The Magnesian Sandstone and the Salt-pseudomorph zone have been omitted by some process of faulting. Then come the coal and associated beds in an outcrop overlying the nummulitic limestone with an inverted dip of 70°—80° northwards. In apparent order beneath this is a small thickness of soft sandstone, which may be Nahan Sandstone, and next to this is a small amount of much shattered Purple Sandstone, and then the Red Marl forming the usual shapeless mounds.

This inversion of the Boulder-bed, Olive series, coal and Nummulitics was traced by me from a position immediately below Dandot for two miles in the direction of the Makrach valley. Along that line the Red Marl gradually approaches the Nummulitics more and more. Owing to this it is scarcely likely that the Nummulitics with the coal bed could have their inversion resolved towards the south, before they become cut off by the invasion of the Red Marl.

Coal was being excavated from this inverted outcrop when I was last at Dandot; but the almost vertical lie of it will prevent deep working. Surface digging may, however, go on along the whole length of the inversion.

The axis of greatest flexure in the above section is of course that in the Purple Sandstone, and as before remarked it is occupied by gypsum and traces of the Red Marl. Again, the greatest reversed fault is that separating the Red Marl (capped by a small amount of broken Purple Sandstone) from the Nummulitics.

Inversion in the Amb glen, east of Seran-ki-dhok.

I will now proceed to a striking example in the Amb glen. The position there is shown in the Sketch Sections Nos. 6 and 7, Plate III. In this western part of the range it will be perceived that the Boulder-bed is overlaid by the Speckled Sandstone without the intervention of the Olive series. The Productus Limestone group is also largely represented. In other places in the glen the Boulder-bed lies directly on the

Purple Sandstone, so that the Obolus Shales and Magnesian Sandstone have entirely dropped out of the scale of formations. The position of the Boulder-bed immediately above the Red Marl might of course be merely the effect of the continued overlap or unconformability that we have before alluded to in connection with it, on the accepted belief that the Red Marl is the oldest rock of the Range. But the relation of the Red Marl to the inverted series below is not altogether so simple, nor is the persisting thinness of it as a band or tongue, protruded along one of the thrust-planes following on the sigmaflexure, without certain noteworthy points.

The following is a condensed summary of the facts represented in Sketch Section No. 7, and in the near neighbourhood of that section:—

(1) The Red Marl appears along two lines crossing the section as thin bands, and forming the cores of flexures. The upper one of these is associated with a fold of the rocks on the sigmaflexure pattern, in which the middle limb of the fold, though much reduced in size, is perfectly recognizable. The formations represented in the middle limb are, however, much crushed and torn along wavy parallel lines, a feature most marked in the compact Speckled Sandstone beds.

(2) The Boulder-bed is peculiar in some ways. It is a dark purple, inky coloured shale, full of large and small boulders of crystalline rocks, and with light drab coloured sandstone beds associated with it. It sometimes attains a thickness of 200 feet.

(3) I could not find in the Boulder-bed immediately above the Red Marl a single patch of the latter as a boulder or block; nor have I ever seen it, though constantly on the look-out for it, incorporated with any other formation. In the Boulder-bed near Pid, which overlies the Salt-pseudomorph zone, there are many patches of the latter rock as it were caught up and whelmed among the other boulders and rock fragments. In spite of the softness of the Red Marl, I think one would expect some trace of it also to appear incorporated in the Boulder-bed, were the latter truly of later formation than the Red Marl, as witness the boulder clays of England, especially in the neighbourhood of Cromer, in which large masses of soft rocks are often whelmed.

(4) In strong contrast to the bedded and sheared condition of the formations included in the middle limb of the sigmaflexure, is the composed, homogeneous structure of the tongue of Red Marl, which is not more than 40 feet thick. It retains its completely unstratified aspect with a sponge-work of thin tabular plates of gypsum running through it in all directions and with thicker lenticular layers of gypsum. This point is, I think, of no small importance, for if the marl was passive under the sigmaflexural movements, it seems reasonable to suppose that it would have been sheared too. But it has not been sheared; there are no traces even of slickensides in it. Could this section be seen by a geologist unprejudiced by a previous theory, he would conclude that the marl band had been forced in a plastic or liquid condition through the rocks and had solidified quietly with the formation of the gypsum spongework under conditions of no strain, after the earth-movements had ceased.

(5) At the lower end of the glen, the very much disturbed sections show great

thicknesses of the Purple Sandstone, too great to imagine thinned away within a few hundred yards. A more prominent unconformability at the base of the Boulder-bed than is elsewhere seen would no doubt account for this, but so would an abnormal position of the Red Marl beneath it.

(6) That the Red Marl is sometimes quite abnormal in its underlie is seen in Sketch Section No. 8, Plate III, where it cuts across the Speckled Sandstone, changing its position abruptly from one inferior to the latter to a position above it and in contact with the Lavender beds. This position is paralleled by the one at Chambal mountain (west) mentioned by Mr. Wynne (p. 150 of his memoir) and explained away by faulting—an explanation not altogether satisfactory.

Section near the mouth of the Golawala Khere glen.

In Sketch Section No. 9, Plate III, there is represented a relation of the Red Marl to the surrounding formations very similar to that east of Seran-ki-dhok. The thickness of the protruded tongue of the Red Marl and gypsum is relatively greater, and it surges forward to the south like a foam-crest above a curling wave of Speckled Sandstone, &c. As before, it is difficult to believe that the Red Marl was a passive and solid formation when this forward ride across the edges of the Speckled Sandstone took place.

The distant hill of Purple Sandstone comes normally above the Red Marl and is of great thickness.

Section near Chideru.

Sketch Section No. 10, Plate III, is given for two reasons. In the first place it exemplifies once more the sharp reflexed folding of the rocks in connection with the Red Marl, and in the second place it possibly explains those apparent interbeddings of the Red Marl with the Purple Sandstone which have been sometimes reported. It also shows veins of gypsum passing outwards from the Red Marl into the Purple Sandstone. These may however be merely secondary veins, and not due to any primary intrusive capacity of the marl.

Section near Swas.

The next Sketch Section, No. 11, Plate IV, near Swas, is here mentioned, rather out of place, on account of its similarity to No. 10. But besides the reversed folds involving the Boulder-bed and Red Marl, there is a much fissured and drawn out inverted middle limb of an incomplete sigmaflexure to the south of the lower band of Red Marl.

It will be noticed that the apparent interbedding in the above section is in respect of the Red Marl among the Boulder-bed. This would be impossible as a real condition, if the interbedding with the Purple Sandstone be also granted.

Section two miles north of Buri Khel.

I now come to the very important section two miles north of Buri Khel. The following points were elucidated with special reference to the questions at issue :—

(1) The Boulder-bed is in direct conjunction with the Red Marl and its contained dolomitic and gypseous masses. It is of great thickness (more than 100 feet), of dark purple matrix, which is a fine hard clay splitting into little jointed pieces. In this and other respects it exactly resembles the Boulder-bed of the Amb glen.

(2) I paid particular attention in this locality, as elsewhere, to the included

fragments, because, in its position here immediately on the top of the Red Marl, there seemed a chance that fragments of the latter might be found in it if the Red Marl had ever formed a floor on which the Boulder-bed was deposited. By the strictest search I could not find a single example of a boulder of Red Marl in the Boulder-bed. I could not find any patch or smudged blotch of it; no trace, in fact, that the Red Marl was older than the Boulder-bed.

(3) On the other hand, I found a considerable number of pebbles of a hard compact, whitey-grey, sometimes faintly pinkish dolomite.

(4) On going down to the Red Marl the cause of the large quantity of the dolomite pebbles in the Boulder-bed above was made abundantly clear; for among the Red Marl there were large massive aggregates of it, which in the central portions exactly resembled the pebbles from the Boulder-bed. I say the central portions advisedly, for, as a rule, the dolomite in the Red Marl, though generally resembling that present as pebbles in the Boulder-bed, was seen to differ from it in this particular: it was always honey-combed, or reticulate, with gypsum filling in the holes and meshes, as already mentioned in this paper. The finely punctured lumps and masses of the dolomite were the most numerous, and they were hard and strong and well capable of forming into pebbles.

(5) None of the pebbles of the dolomite in the Boulder-bed showed any punctures or ragged holes or any change anticipatory of a change into gypsum or Red Marl. This generalization was not made without due examination of every pebble that could be found, both at this particular locality and also at others further west. The following deductions seem to me to be legitimately drawn from the above remarkable facts:—

(*a*) That the dolomite in the Red Marl represents an original rock at least older than the Boulder-bed.

(*b*) That the Red Marl, gypsum, and honey-combed structure in the dolomite are of more recent age than the Boulder-bed at least, in as much as none of these rocks or rock structures are found included in the Boulder-bed, whilst the associated and rare unchanged dolomite is included in large quantities. A slight exception, however, is found in the layer (a few inches thick) of the Boulder-bed in immediate contact with the Red Marl. This is very noticeable, and along with it is a change in the colour of the matrix of the Boulder-bed, which instead of being deep inky purple is a pale dull grey.

(*c*) That some form of metamorphism caused the 'corrosion' of the dolomite, and associated rocks, and the formation of the gypsum from them; whilst the Red Marl was also either produced in a similar way, or was partly so produced and partly extruded from some subterranean magma that, in addition, contained chloride of sodium and the other salts that have since solidified into the well known masses of rock salt from which the range takes its name.

(*d*) That the thin altered layer mentioned in the second paragraph (*b*) is most probably a contact alteration.

The section at Kalabagh.

The following Section at Kalabagh, No. 12, Plate IV, has always been a puzzle of no simple order on the accepted idea that the Red Marl is the basal formation of the Range. I have copied it from Mr. Wynne's own drawing (Memoirs of the Geological Survey of India, Vol. XIV, p. 269), as it is not his observations but his conclusions which must be called in question with regard to it. I have, however, altered the index names of the conglomerate and the Tertiary Sandstones, in conformity with later observations made by Mr. Wynne and by Dr. Waagen.

It will be observed that in that section the orange coloured beds (called the Orange series by Dr. Waagen in his Geological Results, Vol. IV, Part 1) are in direct superposition on the red, white, grey, or bluish-grey rock salt of the Saline series.

I infer from the following considerations that this junction cannot be a normal one due to the deposition of these beds on the top of some exposed reef of Salt Marl:—

(1) The Orange series, whatever be their particular age, undoubtedly belong to the younger Tertiary epoch, and may with certainty be placed stratigraphically somewhere above the Nahan Sandstone and somewhere beneath the Upper Siwalik Conglomerate. Stated differently, they are the middle portion of a geological and petrological series, of immense extent and thickness, which covers vast regions on the North-West-frontier, along the southern borders of the Himalaya, and in Assam and Burma. Throughout this great extent of territory the middle rock-stages of that series are never found in superposition above anything but a lower stage of the same series. What is perhaps of more importance for the present argument is, that in the immediate neighbourhood of Kalabagh, along the very wonderful and striking section up the Indus river from that place, the same fact is above all manifest. There is no trace of unconformability in it.

(2) A still more comprehensive local generalization may even be made. The Tertiary system as a whole, though showing a distinct break between the Nummulitic Limestone and the Nahan Sandstone, does not anywhere in the Panjab exhibit the Nahans superposed above anything but nummulitic strata. Thus, there is no parallel instance anywhere in the Empire on which to frame a line of marked unconformability among the middle stages of the Upper Tertiaries, and we must therefore admit that the abnormal junction of the Orange series on the top of the Saline series is not due to the position of the Orange beds above, but to that of the Saline series beneath.

(3) A further point strengthening this conclusion is that the Orange coloured beds, composed of soft sandstones and clays, or shales, begin as such immediately in contact with the salt-bearing beds. There is no basal conglomerate, and there is no gradual or rapid change downwards in the nature of the sediment of the Orange series as the Saline series is approached—nothing to indicate the beginning, at this point, of a set of

detrital rocks of such marked features and extent as those of the Upper Siwaliks.

A painting with the foreground and middle distance cut away would not more plainly indicate mutilation than does this ruptured section of the Orange beds.

According to Dr. Waagen, the whole of his Red series, Grey Sandstone series, and Purple series, which come beneath the Orange series, are absent in this Kalabagh section, whilst they are in full thickness further up the Indus river.

In the Sketch Section above, I have copied from Mr. Wynne's figure, because I think it truly represents the relation of the rocks visible on the river face.[1] In his Trans-Indus memoir (Memoirs, Geological Survey of India, Vol. XVII, part 2, p. 46) a section through the same hill, but along a different line, is given. As it primarily represents other points, the above relation of the Orange series to the Saline series is not given due prominence.

I cannot here enter into a lengthy discussion of the many other features of disturbance so remarkable in the Kalabagh hill. I refer the reader to Mr. Wynne's Trans-Indus Memoir, pp. 41 and 42. The laboured explanation there given on the accepted age of the Saline series will be at once seen to be unnecessary, if, as I have advocated, we look on the latter as having formed part of a liquid magma forced into and among the rocks in a *quasi*-intrusive fashion.

I will conclude by drawing attention to one final point. As we travel westwards from Kalabagh, the Salt series (Red Marl, &c.) appears no more in what has hitherto been called its normal position. One isolated patch of it appears some eight miles up the Lunai N., but among the Siwalik Sandstones. If the latter means anything, it indicates that the Saline series is trending northwards; whilst the outcrops of the older strata (previously in contact with the Salt Marl) are, as will be seen from Mr. Wynne's Trans-Indus map, trending southwards, or in the opposite direction.

The salt-bearing beds, indeed, seem to have become divorced from the older rocks of the region, and become insinuated among the Tertiary strata. Hence the appearance of the rock-salt of the Kohat region at a Tertiary horizon offers less difficulty to the understanding than before. Notwithstanding the reported differences in appearance between the Kohat salt and that of the Salt Range (as to which I can say nothing from personal experience) I think that, being an appearance and nothing more, it should not carry much weight, when balanced against the strong presumptive evidence in favour of their common origin inherent in the whole circumstances of the case.

Inliers of the Red Marl.

There now remain to be briefly mentioned some few inliers of the Red Marl at two or three places. On the plateau part of the range the Red Marl, with gypsum and sometimes rock salt, appears in the form of little oases among the younger rocks, interrupting them. I was greatly impressed by these occurrences on reading Mr. Wynne's memoir and examining his map, for they seemed utterly at variance with what would be expected of a dormant stratified rock. I was confirmed in this opinion after Mr. Datta and myself had visited the localities; but owing partly to the gentle lie

[1] Perhaps a little exception may, however, be taken to the violent nature of the contortions in the Orange series. The curves might have been much more gently represented, if the true vertical scale in relation to the horizontal had been adopted.

of the country, and partly to the baffling disintegrations of the Nummulitic Limestone, actual contact sections were difficult to realize. With regard to the Kallar Kahar oasis, I have nothing of importance to add to what Mr. Wynne has written (p. 183). The Red Marl shows up at the surface on the south side of the lake, but elsewhere there are no clear sections, free from *débris*, that it would be worth while to describe.

Vasnal oasis.

The examination of the Vasnal oasis was entrusted to Mr. Datta. The following is a summary of the facts that he was able to glean. The valley is a north and south irregular oval, opening into the lower country towards the north-west. It is three miles from the exposure of Red Marl in the neighbourhood of Bhadror, and a greater distance from the Nurpur valley. The bottom of the depression is occupied by Red Marl, gypsum, and some few salt beds. On the north at Tirwa peak, on the east side, and on the south side it is hemmed in by cliffs of nearly horizontal Nummulitic Limestone, the junction being generally covered by the usual talus from the scarps above. The western side is more complicated, being interrupted by three faults running respectively E.—W., E.N.E.—W.S.W., and N.E.—S.W. At the south-west corner the Red Marl is in contact with, and underlies, the Purple Sandstone, which is much slickensided, crushed, and faded in colour. The latter dips W. by S. and is overlaid by a regular, though badly exposed, ascending series of formations up to the Nummulitics.

The E.—W. fault separates this from the Nummulitic Limestone on the south side of the oasis. Traversing the line of contact of the Red Marl and Purple Sandstone for a quarter the length of the west side, the E.N.E.—W.S.W. fault is crossed, and the Red Marl successively comes in contact with a group of formations from the base of the Productus Limestone up to the Nahans, all of which strike obliquely agains the Red Marl in a N.N.E. direction. Underneath Tirwa the arrangement of the rocks is vague and difficult to follow. It has been described by Mr. Wynne in his memoir (p. 197) with a sketch-section. The latter is instructive as showing what a hopeless task it would be to reconcile the *allure* of the Red Marl at that place with a theory of it as an inert stratified rock.

The Vasnal inlier, therefore, is surrounded on all sides, except a quarter of its western side, by an abnormal line of junction—just such a one as an intrusive, or *quasi*-intrusive, rock would make for itself by bursting through a fissure, but which would be difficult to account for by a combined system of small faults.

Sections near Ainwa.

The following account of the relation of the Red Marl and gypsum masses to the surrounding rocks in the neighbourhood of Ainwa (Aninwa) is an abstract of the very interesting detailed notes supplied me by Mr. Datta, who visited this locality alone.

In the plan, Plate IV, is seen the surface arrangement of these masses and bands, chiefly of gypsum, and with but little Red Marl in them. About 400 yards south of Ainwa (of map) gypsum is first found in bands from one to two feet thick, apparently intercalated with the Upper Tertiary (Nahan?) sandstones and hardened clays, which are strongly impregnated with gypsum. The area in which they are found (indicated by the dotted oval in the plan) is disturbed as to its strike in relation to the prevailing N.W.—S.E. strike on either side of the area.

Between that area and the gypsum hill there are no regular bands of gypsum, but the clays of the Nahans are impregnated with it. The mass of gypsum forming the hill is peculiar, in that it appears on the north and west sides to rest on or against the Nahan Sandstones, whilst on the south it appears to lie on the alluvium. After allowing for a certain amount of surface slipping down the hillside, it remains probable that it passes downwards through or among the Tertiary Sandstones in the form of a "neck" or a series of closely approximating bands.

At the south-west corner of the hill there are two small isolated exposures of the gypsum which were doubtless originally connected with the larger mass. An isolated outcrop of Nummulitic Limestone S. by E. of the hill is an indication of irregular disturbance in this neighbourhood.

Mr. Datta remarks: "Not only are the Tertiary clays and sandstones occupying the valley in which Ainwa (of the map) is situated highly impregnated with gypsum, even when the beds show no sign of disturbance, but the whole tract of country in this neighbourhood exhibits an amount of gypsum in the rocks not observable elsewhere. Between the valley and Ainwa village (which is about a mile east of the valley), I found veins of gypsum in joints of the grey sandstone cutting obliquely through the bedding. It appears to me that the gypsum of the hill, and the gypsum bands in the disturbed area of the valley south of Ainwa (of the map) are contemporaneous; that the gypsum must have come up from below through a fissure or some other vent; that some of it forced itself along the bedding planes and became thus apparently interbedded with the clays and soft sandstones, but the main mass accumulated on the Tertiary clays and sandstones forming what is now a hill; and from the same source which gave rise to the hill, the neighbouring Tertiary beds became impregnated with the gypsum."

The gypsum bosses or bands south of the hill and marked on the plan as A, B, C, are of slightly different import. They mark a line of great faulting between the Nahan Sandstone to the north and an inverted series consisting of Boulder-bed and Speckled Sandstone to the south. Thus the gypsum, Boulder-bed, and Speckled Sandstone are in the same order as the middle limb of the sigma flexure on the west side of the Amb glen. It seems evident that the gypsum forming these lenticular masses was forced up along this line of dislocation. Mr. Datta states that there is hardly any Red Marl associated with the gypsum. Presumably, however, there is sufficient to identify the material as belonging to the Saline series.

Sketch Section No. 13, Plate IV, drawn along M. M. on the plan, is copied from Mr. Datta's notes. It illustrates the foregoing description, and in addition shows one of the gypsum masses D. E. F., which appear overlying the truncated edges of the Speckled Sandstone, &c. It was probably once connected with the protruded tongue A. B. C.

(3) *Concluding hypothesis.*

The intrusive theory not original, though not now accepted.

The nature of this paper as a mere collaboration of field work, written practically in camp, and at a great distance from books of reference, makes it impossible to treat fairly the views of other geologists on the subject of the origin and age of these salt-bearing beds. From the remarks made by Mr. Wynne in his memoir (pp. 12, 13, 15, 26, 82, 83) it will be seen that he was fully aware of, but unimpressed by the fact that inferences analogous to those drawn by me have been entertained by previous observers. Also I think there can be no doubt that modern geological thought as a whole does not in the least regard seriously such explanations as I have so far given or implied, and which I shall now embody in a single sweeping hypothesis. I believe the geologists of to-day are few, if any, who would extend the scheme of rock formations so as to include one coming in such a questionable shape as this. Hence I must rely on my own facts detailed before if I would drive home a conviction, even though it be founded on an old idea.

Absence of metamorphic rocks below the Cambrian strata. No slate series.

Let me begin by pointing out that the area of the Salt Range presents some peculiarities of its own that may warrant us in looking for exceptional subterranean conditions in this region. For instance, we now know, beyond possibility of dispute, that the trilobite-bearing shales of Khusak fort date back into geological history almost as far as the present records can take us. But instead of these Lower Cambrian rocks resting on a Pre-Cambrian or Archean floor of gneissose or schistose rocks, we find them placidly reposing on a Purple Sandstone of much the same firmness and aspect as the Old Red Sandstone of England. The Purple Sandstone is totally devoid of metamorphism in the strict sense of the word. What is true of the lowest rock-group in this respect is of course true of all the succeeding younger formations. In addition to the absence of any metamorphic strata in the range, there is also wanting everything in the nature of a Slate series—there is not a slate in the whole country. Look where we will in the Salt Range, we can find no suggestion of the action of plutonic heat or deep-seated compression on the rocks from Palæozoic times up to to-day.

No contemporaneous or intrusive igneous rocks from Cambrian times upwards.

Another instance illustrating peculiar subterranean conditions is, that through the whole of the stratified rocks, which embrace so rich a fauna of the Palæozoic, Mesozoic, and Tertiary eras, there is no single example of an igneous rock, neither in the form of contemporaneous bedded lavas, &c., nor as dykes or plutonic masses.[1] It needs no words to show the probable connection between this peculiarity and the absence of all metamorphism.

The subterranean magmas have remained sealed up.

Shifting the aspect in which we regard this phase of the question, it is clear that the subterranean magmas, whether liquid from molten or aqueo-igneous conditions, have remained sealed up since the time of the oldest stratified rocks. Nothing of those magmas has ever been drawn off by volcanic vents. Hence, all the gases, water substance, and other constituents, that in other parts of the world have found access to the surface during periods of eruption, have in this region never approached sufficiently near to the surface to make their escape.

It follows, therefore, that if we could bore through the crust of the earth, we should either let loose the slumbering magma beneath, or we should come upon a solidified layer representing the potential volcanic activity arrested and smothered

[1] The only volcanic rock *in situ* in the Salt Range, in fact, is the Khewra trap found always associated with the Salt Marl. This peculiarity is commented on in Mr. Wynne's memoir (p. 83), and reference is also made to the like association of dolerites and trachytes with the salt rocks of Hormuz in the Persian Gulf, described by Dr. Blanford (Rec., Geol. Surv. I. Vol. V, p. 42).

before birth. Moreover, it would represent a potential volcanic activity that at some level or other beneath the surface had been continuously kept prisoner since the Cambrian epoch.

The hypothesis of the Salt Marl as a scum or secretion, resulting from a long-suppressed, potential, volcanic activity, which had become extinct.

The question now suggested is, Can we see in the homogeneous structure and composition of the Red Marl, in its freedom from all traces of sedimentation, in its signs of a derivative origin from bedded dolomitic strata, in its contained beds of salt and gypsum, in its association with the Khewra trap, and in its anomalous *quasi*-intrusive relations to other formations—can we see in all this the actual embodiment of such a potential activity? Can we see in it anything of the nature of a scum, such as we might picture to ourselves as having partly secreted at the surface of an ancient untapped magma, and partly resulted from that secretion by induced changes in the overlying dolomitic strata?

If we can, we have but to give the substance a gently intrusive or injective impetus, followed by consolidation, some time during the Tertiary period, to account for all the otherwise perplexing circumstances under which the salt-bearing beds of the Panjab are found.

In such a hypothetical state I must reluctantly leave the enquiry for the present.

On Veins *of* Graphite *in* decomposed Gneiss (Laterite) *in* Ceylon[1]; *by* DR. JOHANNES WALTHER, *Jena.* (*Translated by* R. B. FOOTE, F.G.S., *Superintendent, Geological Survey of India.*)

Graphite forms the most important mineral export from Ceylon; it is therefore all the more remarkable that up to the present no exact information is procurable concerning its geological occurrence. The statistical and economic relations of the Ceylon graphite were drawn up very fully in 1887 by A. M. Fergusson, the Editor of the great "Ceylon Directory," and laid before the Ceylon Branch of the Royal Asiatic Society;[2] and to F. Sandberger we are indebted for valuable researches into the mineralogical condition of the Ceylon graphite;[3] while briefer remarks about the mineral are scattered in the literature of the island.

The last King of Kandy is reported to have already exported graphite; the Dutch Governor Ryklof van Goens made communications in 1675 about graphite veins in the lowland hills; Robert Knox referred to them in 1681, and the Scandinavian naturalist Thunberg wrote about them in 1777.

The most important mine in Kurungala belongs to De Mel, and lies at foot of the Polgola hill, which is said to consist almost entirely of graphite (?). The pit is

[1] *Vide* Zeitschr. d. Deutsch. Geolog. Gesellshaft, Jahrg., 1889.

[2] On plumbago, with special reference to the position occupied by the mineral in the commerce of Ceylon.

[3] Neues Jahrbuch für Mineralogie, &c., 1887, II, 12.

450 feet deep. Near by, W. A. Fernando has opened a mine 330 feet deep, but at a higher level. The other important mines are situate in the district of Kaltura. According to further communications from A. M. Fergusson the graphite veins strike from south to north in the Western Province and from east to west in the Kurungala district.

From F. Sandberger's work I extract the following physiographical and chemical facts:—The graphite is coarsely foliated or "stalky," and includes kernels of quartz, orthoclase, radiating hornblende, mica, apatite, pyrites, weathered andesine and chloritiferous kaolin. Especially interesting is the occurrence of many colourless rutile crystals and of acicular pseudomorphs of titanic iron which permeate the mass of the graphite.

During last spring, after a visit to the gem pits of Ratnapura (at the southern base of Adam's Peak) I sailed for two days with Professor F. Exner of Vienna in a boat on the Kaluganga to Kaltura, and had an opportunity during this trip of examining a graphite mine, and the geological appearance of the mineral may deserve some little interest.

About halfway between Ratnapura and Kaltura a bar of hard granite closes the bottom of the valley, and the river forms a violent and dangerous rapid. On the left bank lay great heaps of graphite blocks which had been brought out of the jungle by coolies and which were being shipped from below the rapid. The graphite was very soft, partly in minute scales, partly "stalky," and blocks of a cubic foot in size, of the finest graphite, occurred in the heaps. Individual blocks consisted of stalk-like parallel masses, 20 centimetres in length, but others showed a very confused structure. Nothing special could be gathered from the coolies about the mode of occurrence, and the pits were too distant to be looked up. The next day, when we were still about six hours' sail from Kaltura, we saw in the scrub jungle, on the eastern bank, a section about 300 paces from the river, and left the boat in order to examine it more closely.

The grey "domoid" gneiss which predominates in that part of Ceylon and which rises everywhere out of the virgin forest in mighty domes of blocks, was here so greatly weathered to a depth of 12 metres that it could be cut with a knife. The product of weathering was a pale red mass of kaolin with many small red spots and individual harder laminæ crumbling into quartz grit. I do not hesitate to term this decomposition rock laterite, as all the transitions exist from the genuine deep red laterite to this pale red-spotted rock which comes to pass *in situ* out of the bedded grey gneiss.

From this light red laterite exposed in the quarry to a depth of 12 metres, a system of much-branched veins of black graphite stands out most conspicuously. Cingalese workmen were occupied in breaking out the graphite with iron picks, and others carried the mineral away to the rock-cut steps.

The main vein strikes nearly E.-W., hades 60° north, and varies in thickness from 12 to 22 centimetres. Many apophyses branch off from the main vein, and other smaller veins, which either split up speedily into small branches, or else unite quickly with neighbouring veins, run parallel with the main vein. In their form the veins differ in no respect from the quartz veins which are so frequently to be seen in the gneiss of Ceylon. I broke out a piece of the main vein with the "Sal-bands" on both sides, and packed it as carefully as I could, but it arrived in Jena in the condition of minute fragments.

The graphite is stalky and the stalks stand perpendicular to the "Sal-bands." By subsequent movements along the cleft the "stalks" have been bent in many places. *The "Sal-bands" distinguish themselves most by their red colour.*

In the laterite outside of the veins I nowhere found graphite in nests or spangles, and the "Sal-bands" also appeared quite free from included specks.

As to the mode of formation of this graphite, four views appear to be possible:—

1.—As graphite has frequently been observed as a quasi-sedimentary inclusion in normal connection with stratified rocks, this assumption should also be tested here and examined to see if an originally horizontally bedded band of graphite might not now be presenting the appearance of a vein-system because broken up and faulted by subsequent dislocations. A careful examination of the locality showed that such a view was untenable, and that the observer is confronted by a genuine system of fissure veins.

The pointed ends of the graphite apophyses have no corresponding extensions, and as far as one can judge from the sandy and clayey bands of the laterite of the original bedding of the gneiss the graphite veins cut such at considerable angles. The only assumption which thus remains possible is that fissures originated in the unweathered gneiss by dislocations, which fissures were filled up with graphite. When at a later period the gneiss decomposed into laterite the carbon-filled veins remained unaltered and are so found in the laterite to-day, a speaking proof that this rock was formed *in situ* and has not been "*remanié.*"

(2).—Although it has just been shown that the graphite here is a true veinstone there yet remains the second and more difficcult question to answer. How did the graphite veins originate, and how could the carbon fill up the fissures in the gneiss? The view that the carbon was forced up in an irruptive condition is repudiated by F. Sandberger on the strength of his observations. Although the geological occurrence of Sandberger's graphite is unknown, it is yet probable that it came from a vein in the decomposed or the unaltered gneiss. The author says: "It can be positively asserted that the igneous method is quite excluded, as the graphite contains iron pyrites which can never originate in the presence of a high temperature, while the acicular rutile crystals would have been reduced to metallic titanium by the great excess of carbon.

(3).—If the graphite could not get into the fissures as a compact (but once molten) substance, it is yet conceivable that a carbonaceous combination dissolved in water might have saturated the rocks and have been reduced to graphite in the fissures. Such a view appears to me untenable for two reasons. Firstly, we are unacquainted with any such process and any such carboniferous solution; and assuming even that such a solution could be established, I do not quite understand why the adjacent rock does not also contain graphite. If the graphite was reduced from an aqueous solution, the entire rock or at least the "Salbands" should be impregnated with minute spangles of graphite. I examined the laterite on the spot carefully in view of this, but could not discover any trace of graphite in it ;the Salbands also were perfectly free from graphite, *i.e.* they were light red in colour without any greyish admixture. Thus, the probability of the carbon having got into the fissures in the igneous way becomes exceedingly small.

(4).—As far as I am able to judge the relations, only one possibility remains, to which there is no serious objection, and which I discussed fully with my fellow traveller on the spot. Although the formation of the graphite as an intruded material, or out of an aqueous solution, meets with serious objections; it yet remains conceivable that it may have got into the fissures in gaseous form. It is not probable that the carbon itself was sublimed; but among the hydrocarbons, rich in carbon, we meet with combinations which are easily sublimed, and, what appears to me yet more important, really play a great part in nature, and perfectly saturate mighty rock formations. Hydro-carbon exhalations are known all the world over, and spectroscopic analysis teaches us that they play an important part in cosmic bodies which are not so far advanced in their development as is the earth. Secondly, we know then in the flues of gas-works and cooking furnaces a substance is deposited which has many properties in common with graphite. It would appear from many experiments that it is from cyanogen compounds that the gas-furnace graphite is precipitated, but for us the fact is important that it is a product of sublimation.

All is strongly in favour of the view that the Ceylon graphite has been reduced from carboniferous vapours, but of what kind such vapours were is another question.

The minerals included in the graphite must then be regarded partly as fragments of the original gneiss, and partly as subsequent segregations from solution.

Whether all graphite has originated in this way is a question that might be difficult of discussion as long as our knowledge of the tectonic occurrence of the graphite remains so imperfect. It appeared to me fairly probable that the graphite which occurs in the gneiss of the Amsteg tunnel on planes of a slickenside was of similar origin.

Anyhow I think I should point out that the view (apparently a very sensible one) that graphite represents the remains of the archaic flora, is not quite tenable.

It is very tempting to place graphite at the end of a progressive alteration series beginning with peat and brown coal and leading up through coal to anthracite.

From the mineralogical side, objections have been made to the inclusion of graphite in this series, and the observations made on the mode of occurrence of the Ceylon graphite are calculated only to increase those objections.

One may hold no decisive views as to the aqueous or gaseous filling of the graphite veins; but at any rate its occurrence in veins will not fall in with the view which regards the graphite as altered cellulose.

Extracts from the Journal *of a* trip *to the* Glaciers *of the* Kabru, Pandim, *&c., by* PRAMATHA NATH BOSE, B.SC., F.G.S., *Deputy Superintendent, Geological Survey of India.*

The following extracts from the journal of a trip to the snowy regions of the Himalaya, undertaken in September 1889, are published partly because they contain geological notes, which, however scanty and disconnected, may be of some value, relating, as they do, to a country but little explored, and partly in the hope that they may be of some service to future travellers. Sikkim is being fast opened up. Last year the Nepal Frontier Road was extended one stage beyond Phalut, that is to say, a stage nearer the snows. And, in a few years, tourists will, I have no doubt, be discussing trips to Aulakthang or Giuchala, as they now do to Sandokphu or Phalut.

There are to my knowledge four published accounts which cover portions of our journey. The earliest and best known of these is the "Himalayan Journals," by Sir Joseph Hooker. His journey in the direction we went, being undertaken in the depth of winter, could not be pushed beyond Jongri, two stages south of the glaciers we reached. He went *viâ* Yoksum, the route we took on our return journey. The next account is that of Captain W. S. Sherwill.[1] The point he reached was a long way south of Jongri; in fact only one stage beyond Migu, our third march from Phalut. The only parties that preceded us, as far as I am aware, to the Giuchala pass, are those of Major J. L. Sherwill,[2] and of the Alpine traveller Mr. W. Graham.[3]

The geological observations interspersed through the Journal, meagre as they are, taken in connection with those on the eastern frontier of Sikkim made by Dr. Blanford[4] in 1870, and by me in October last year on a trip to the Pemberingo pass near Gnathong, enable us to form an idea, though a very rough one, of the geological structure of Sikkim. The central portion consists of glossy mica schists, quartzites, carbonaceous slates, &c., belonging to the Daling series of Mallett.[5] These are surrounded on all sides by gneissose rocks of a distinctly more ancient aspect. A portion of the southern boundary between the Dalings and the Gneiss, which lies in the district of Darjeeling, has been shown by Mr. Mallet to be faulted.[6] On the west side, I crossed the junction at two places, near Lingcham (south-west of Pemionchi) and near Chakang. At both these places, the Dalings and the Gneiss agree in their dips, so that the former pass under the latter. Whether the underlie is real, or only apparent, being the result of a reversed fault, I am unable to say exactly. No trace of the Gondwanas was met with anywhere. My time on the glaciers was too short to admit of detailed exploration. But something, however little, has, I venture to think, been added to our existing information about them.

I am indebted to my fellow-traveller, Mr. J. C. White, Political Agent, Sikkim, for many acts of personal kindness.

[1] J. A. S. B., Vol. XXII, 1854, pp. 540—611.
[2] J. A. S. B., for 1862, p. 457.
[3] Proc., Royal Geog. Soc., Lond., Vol. VI, 1884, p. 429, *et seq.*
[4] J. A. S. B., for 1871, p. 367.
[5] Mem., Geol. Surv. of India, Vol. XI, p. 39.
[6] *Op. cit.*, p. 42.

September 1st to 4th.—It was pouring in the afternoon of the 1st of September when I left Darjeeling. Proceeding stage by stage, reached Phalut on the 4th. As this part of my route is well frequented, there is nothing specially noteworthy about it. The weather was certainly far from fine, and I had to content myself with imagining what views I would have had if it were otherwise. Got drenched every day. But that did absolutely no harm, though I discarded my waterproof, as I found it added to my encumbrance without adequately justifying its name.[1]

Descending from Simana (a village just beyond Jorpokri, the first stage from Darjeeling) an immense development of well-bedded quartzites was found for a considerable distance. Such intercalation of quartzites in the Darjeeling gneiss was met with at various places.

Gneiss occurs at Tonglu; strike very inconstant. Inclusions of large rounded pebble-like fragments of quartzite occur in it, such as may be seen in the gneiss about Darjeeling. They bespeak the original sedimentary character of the gneiss.

The gneiss at some places is highly schorlaceous; and at some places, it contains garnets in abundance.

September 5th.—Leave Phalut at 7 A.M., temperature 48°. There is a fine peak about a mile north of Phalut; it is called Singalela on map, though that should, strictly speaking, be the name of a pass some miles further north. The view from this peak must be grand. But, unfortunately, though I waited for some time for the weather to clear up, it did not do so; and I had to be content with a peep at the lower hills of Sikkim.

Just a little way beyond Singalela, the gneiss was found to dip rather easy, W. N. W. The dip is nowhere high, and the gneiss is not contorted as it is about Darjeeling. Huge blocks of the rock occur on the way. About half-way between Singalela and Chia Bhanjan, white, hard quartzites are largely developed. Near Chia Bhanjan, the gneiss is highly micaceous; strike N. E.—S. W.

Reach Chia Bhanjan at 2 P.M. The place is so marked on map, and, I believe, this is the name given to it by the Paharia (Nepalese) settlers in Sikkim. It is known as Singalela to my sirdar and other Darjeeling people. W. S. Sherwill calls it Tumbok,[2] and Hooker, who entered Sikkim by this pass, designates it Islumbo.[3] I questioned a number of Sikkimites. The last two names they had never heard of.

Chia Bhanjan is, perhaps, the most frequented pass between Sikkim and Nepal. Its height, as marked on map, is 10,320 feet. Leeches are present, but not very

[1] For the benefit of future tourists, I may here mention the disposition of my coolies. I have thirteen, with one sirdar at their head. The coolies get 8 annas a day, and the sirdar a rupee. Three coolies carry my cot, bedding and trunk containing clothes, books, &c.; six take my stores, kitchen utensils, &c.; and the rest my Kabul pâl, one servant's pâl, and the sirdar's impedimenta. The coolies were all very lightly loaded, about 20 seers each on the average, as they had to carry, in addition, their own food for one fortnight.

[2] J. A. S. B., Vol. XXII, 1853, p. 561.

[3] "Him. Journ.," Vol. I, p. 280. In the map accompanying Sir Richard Temple's paper on "The Lake Region of Sikkim," (Proc. of Royal Geog. Soc., Vol. III, 1881, p. 321), the pass is named Islumbo. I am told that this is the name by which the pass is known to the Nepalese in Nepal.

plentiful. I have not been troubled with them since leaving Joopokri, where the ground about the bungalow is terribly infested by those blood-suckers.

Materials are being collected for a bungalow to be built here soon; it will be one stage nearer the snows.

September 6th.—Halt to meet Mr. J. C. White, Political Agent, Sikkim. He comes up in the afternoon.

On the Nepal side, just a little way below my camp, there is a dark-looking tarn, enclosed on all sides and surrounded by dense rhododendron and bamboo jungle. It appears to be fed by a spring close by.

September 7th.—As W. made a long march yesterday, the whole of his camp could not come up last night. While waiting, he offers me a drink of *murwa*, a most delicious beverage, which there is hardly any traveller in Sikkim who has not tasted and enjoyed. I have heard it praised even by rigid teetotallers. Amongst W's retinue is the Secretary of the Sikkim Council, called Dingpun, and an interpreter, named Nimdarji.

Started from Chia Bhanjan at 9 A.M. Proceed along the ridge which forms the boundary between Sikkim and Nepal. It is the continuation of the Gum-Phalut ridge, and is known as the Singalela ridge. It forms a well-marked watershed, the streams issuing from it on the west side forming tributaries of the Ganges, and those on the east side pouring their waters into the Tista, a tributary of the Brahmaputra.

Our route lies through a rhododendron forest; pass several sheep pastures. The footpath is fairly good, and could easily be made practicable for ponies.

The dip of the gneiss is usually low, seldom exceeding 30°. The direction of the dip is east-north-east to north-east. Highly foliated schist near a place called Nyatar, where we encamp on the Nepal side at an elevation of 11,000 feet.

With regard to the heights taken by us, I may say that they were all determined by W.'s aneroid, the error of which was satisfactorily found to be very small, and for which allowance has been made. My own aneroid is most unreliable. Its error has been increasing with the height, and that too most whimsically.

September 8th.—Early in the morning W. calls me up, and we have a very fine view of the Nepal snowy range. One fine peak with an armchair-shaped, crater-like hollow in front is very conspicuous.[1]

Set off at 8 A.M. Walk through a rhododendron jungle as yesterday. Pass a small dirty pond on the way, which is called Parmu pond on map. Ascend a peak, called Lampheram on map; but the name is not known to the Sikkimites. One of them called it "Sagu," which is the name used by W. S. Sherwill,[2] who passed this way. Passing Lampheram (Sagu), the dip of the gneiss is seen to be north-western at places. The footpath passes along the crest of a ridge through scrubby sweet-scented rhododendron and stunted juniper. The view into the abysmal valleys on either side is superb. Ascend a peak higher than Sagu (over 13 000 feet), then descend, and go along the flanks of a ridge over much broken up gneiss Camp on a fine undulating grassy plain, at or near a place called Migu. Elevation 12,500 feet.

September 9th.—My sirdar, whom I engaged on the strength of his assertion that

[1] I cannot find out its name. W. S. Sherwill refers to it, *op. cit.*, p. 615.

[2] *Op. cit.*, p. 570.

he was well acquainted with the route we had taken, has hitherto been acting as our guide. To-day he took us off the right track and up a ridge at a height of about 14,500 feet close to Negadachenphuk.

Pass some slaty-looking rocks. They are, in reality, very fine grained, thinly bedded gneiss. Veins of quartz-rock and of a granitic looking rock are rather common. The dip of the gneiss is very low; it is almost horizontal at places. The direction of the dip is east-north-east to north-east.

Plenty of wild rhubarb. When thirsty, it is very refreshing, being pleasantly acid; it also makes a very nice stew. Of the jungle produce, we have, besides rhubarb, mushroom and bamboo shoots. The Lepcha coolies have a very keen eye for mushrooms. They can easily tell which are edible and which not.

At a height of about 13,500 feet, the gigantic mountain rhubarb, of which a figure is given by W. S. Sherwill,[1] and another huge thistle-like flower are met with. Ascending 14,500 feet we find the ridge to be very narrow, with precipitous sides; and our further progress is stopped by the absence of a track practicable for laden coolies. The sirdar and some others of our party go in different directions searching for a practicable path. The search, however, proves fruitless, and all come back, except the sirdar, who keeps away, convinced probably of his mistake. We retrace our steps, get down close to where we camped yesterday, and then come up on the right track which keeps to the valley of the Yungya (Changthap on map), and is rightly marked on the map. We are drenched as usual, and too tired to make much progress; so we camp at a sheep clearance not very far from our last camp, and just at the foot of the hill which we got up in the morning. The sirdar was howling like a raving maniac above us. He is called back and brought down to his proper level. Henceforth he is deposed from his position as guide.

September 10th.—Start at 7-30 A.M. Proceeding a short distance from our camp, the path, which is a sheep track, bifurcates: one, leading to Yampung, goes along the crest of the Singalela ridge, and the other keeps to the valley of the Yungya. We take the latter, and pass, as we did yesterday and the day before, over shivered blocks and fragments of slaty-looking gneiss; enormous masses of quartz-rock and of a granitic-looking rock are met with at places. The shivering of the gneiss has been effected by frost. There is no rock *in situ* for some distance on either side of our track so far as the eye can reach—and it cannot reach very far on account of the mist—all is a confused mass of more or less angular *débris*. Beneath us we occasionally hear the gurgling of a streamlet.

To our left the gorge of the Yungya (Changthap), thousands of feet deep, and several roaring silvery cascades, rushing down the steep slopes of the Kangrangla ridge, form a scene of weird, wild, but sublime magnificence.

We reach a small lake—one of a group of several about here. The lake is very shallow; its water beautifully pellucid. The floor of the lake is a kind of mosaic pavement made up of large and small angular flat pieces of rock with coarse sand in the interstices. At the lower end of the lake issues a stream which courses

[1] *Op. cit.*, p. 618. Sherwill describes the plant as follows:—"It consists of a conical assemblage of buff-coloured leaves of great beauty, elegantly crimped, and edged with pink, the whole growing upon a substantial stem, upon which and hidden by the graceful leaves are bunches of flowers and triangular seeds somewhat resembling mignonette; the plant measures 45 inches in diameter at the base of the cone and is about the same height."

its way amongst large angular fragments of rock curiously packed in a wavy manner.

From the small lake we proceed westward and clamber up a steep track discernible only by slabs of stone put up at places by shepherds, who are the only frequenters of these wild solitudes. In summer they take their sheep nearly up to the snows; and as the weather gets cooler, they come down to lower elevations. Pass a deep gorge with precipitous sides at the head of the Yungya, and reach a fine, large lake. It is called Timbu by a Gurung from a neighbouring sheep pasture. Last three days we were on the border of Nepal; to-day we are right in it. Camp just by the lake on very sloppy ground at a height of 14,010 feet. The sweet-scented scrubby rhododendron, grass, a kind of thread-like white lichen, and moss, constitute the flora of this place. Fuel has to be brought up from a distance: we are above the limit of fuel. Weather very misty and wet. Thermometer at 5-30 P.M., 40° F. Boiled water at a temperature of 79° at 3 P.M.

September 11th.—Halt. 6 A.M., thermometer, 42°. Very few civilized people, if any, have ever visited this beautiful lake, not even, apparently, the gentleman who constructed the survey map. W. S. Sherwill saw it with his telescope from the top of the Singalela ridge.

The lake runs nearly E.—W., instead of N.—S. as represented on map. It is about a quarter of a mile in length. The western and northern banks are very high and precipitous. On the south and east sides the banks are very low. At the south-eastern corner issues a small, but rushing torrent. On the south and east side (where the banks are low) there is a fringe of stones of all sizes laid flat, all more or less angular and packed close with fine micaceous sand in the interstices, just as in the small lake we passed yesterday morning. Along this fringe the lake is very shallow; but beyond, it is deep; how deep I could not ascertain.

Along a portion of the south and the whole of the east side, the rock is massive and granitic-looking, with usually black crystals of hornblende. Over a portion of the south side, however, the slaty-looking gneiss which I have been encountering all the way from Migu is present. The gneiss is very fine-grained and thinly bedded. and passes, at places, into mica schist. Quartzite is interstratified with it; and it is capped by the granitic rock mentioned above. The latter has, in all probability, penetrated as a dyke. The dip of the gneiss is very low, not exceeding 10° or 15°, and points S.-W.

The Timbu lake and the one we passed yesterday morning do not appear to be of glacial origin. No moraines occur anywhere; rock *in situ* forms the bank on all sides. At this elevation (14,000 feet) the water of the lakes must be frozen up in winter, and with it the frost-shivered rock débris. On the melting of the ice, the latter are probably laid down on the floor of the lakes in the manner described above.

September 12th.—6 A. M., thermometer, 40°. Leaving Timbu and retracing our steps we get back to the little lake we encountered day before yesterday, and walk northward. Pass a number of such shallow lakelets on the way. Several sections occur in which the granitic rocks mentioned above are found to all appearance interbedded with the low dipping, fine-grained, thinly bedded, slaty-looking gneiss. They may be intrusive sheets. Two varieties of the granitic rock were met with, one containing abundant nests of white mica, and the other with plenty of hornblende. The thickness of the granitic rock varies from a few inches to 15 or 20 feet.

Cross over to the Sikkim side by a good pass. Here the path bifurcates, one branch going to Yampung, and the other to Jongri. We take the latter, and proceed in a general northerly direction.

A short way beyond the pass, the fine-grained gneiss is entirely lost sight of. We have massive crystalline rocks instead. They are very largely developed; huge masses of bare white rock towering above us present a most picturesque appearance. The crystalline rocks are of two types—one with hornblende, and the other without it. The latter is composed of felspar, quartz, and black mica; a sort of foliated arrangement is discernible in it; it is, in fact, a granitoid gneiss, or gneissose granite. These crystalline rocks are in all probability of intrusive origin. Their presence strengthens the suspicion that the similar granitic rocks found apparently interbedded with the fine-grained gneiss about Timbu and other places are intrusive sheets.

We descend down a deep gorge along a roaring streamlet (a feeder of the Yangsap); and following a track not indicated on the map descend down to the level of firs (about 12,500 feet). Here we encamp at a place called Gamothang,[1] by the side of a rushing torrent. It is a sheep-grazing station. There is a shed here, with stone walls and a roof of fir planks.

The view from here in all directions is lovely. The deep, dark gorge we have left behind, the bare white granitic peaks rising majestically above us, the roaring waterfalls, the fir forests, and the deafening noise of the stream we have camped on, all combine to produce a most pleasing effect.

September 13th.—The weather all along has been very misty and wet. It cleared up a little this morning at 6, but turned misty soon after. Crossing the stream by our camp over two logs thrown across, we pass through a jungle of rhododendron, rose, cherry, fir, &c., and climb to a place called Bokto (height 13,350 feet). It is a yak-grazing station, a fine, large, open bit of land. The bulls are fine animals, with long bushy tails. As it is raining, we enter the shed of the yak-graziers to rest awhile; and W. orders a yak to be got ready for riding. The shed is of the same description as the one we left behind at our last camping-place. It is 24′ × 12′. The calves, women and children, all herd together in it. The people not having any ideas of sanitation or of esthetics, our senses of smell and sight are sorely taxed; in fact, the place is a veritable den of filth. The male keepers being away, we find only women and children in it. The inmates are very healthy-looking; and a buxom young lady is the prototype of the proverbial milk-maid of Bengal. They are doing very brisk business with the coolies, selling butter, curd, &c., &c. They protest there is no yak fit for riding. Some attempt, however, is made to saddle one, but he plays all sorts of antics to the great amusement of the coolies, and the attempt is given up as fruitless. There is a pass leading into Nepal from Bokto.

Leaving the shed, we get up a little higher, and then descend into the valley of the Yangsap. Elevation 12,400 feet. We then get up a saddle, 13,800 feet in height. Reach the valley of the Kamzar at 3 P.M. Elevation, 13,050 feet.

The rock all the way is massive coarse gneiss. Foliation is more or less distinctly observable everywhere. The strike was observed at one place to be N. W.—S. E. The fine-grained, thin-bedded gneiss is nowhere met with.

[1] The place marked as such on the map is not known by that name.

September 14th.—Temperature, 6-30 A.M., 44°. Start at 7-30 A.M. Get up a ridge 13,900 feet high. Here we meet the path to Kanglanamo, one of the most important passes between Sikkim and Nepal—that by which Thibetan salt comes into the western parts of Sikkim. W. had arranged that we should go to the pass; but the weather being misty and wet, the idea is given up.

We descend into the valley of the Ratong (at its head). The descent is very steep. Fronting us is a foaming, roaring waterfall, the grandest we have seen so far. Cross the Ratong over two bridges, which, being made for the sheep to cross over, are not so bad. Ascend again along a rather gentle slope. To our left a perpendicular wall of massive gneiss, some 500 feet high, towers majestically above us in the gloom of the misty weather.

Massive gneiss with veins of white granitic rock all the way. The gneiss is at places highly schorlaceous.

Reach Jongri at 3 P.M., drenched as usual. The height of our camp, which is close to a shallow lakelet, is ascertained by W. to be 13,100 feet.

Jongri literally means, I am told, "fort-hill." Whether there ever was any fort here is doubtful. There are some ruins scattered about; but they are by no means imposing-looking, and may formerly have belonged to no grander structure than a yak shed.

September 15th.—7-30 A.M. temperature, 45°. Weather misty, as usual. Drizzling. No view.

The food of the coolies having been nearly exhausted, W. sends down to Yoksum for rice, &c., and orders a yak to be killed for their present benefit.

There are two yak sheds here in good condition. One of these is two-storied. The calves are accommodated in the lower floor, and the upper is used by the yak keepers. The head keeper is a rather dignified looking old lady. W. asked her over yesterday to our camp to enquire about the condition of the path we have to traverse. He gave her some rum, which disappeared down her throat undiluted and with marvellous rapidity.

The country about Jongri is undulating, and there is very fine pasturage; it is the most extensive piece of gently undulating ground that we have met so far, being well suited for a settlement. The killing of the *yak*, and its distribution among the coolies, delay us a little, and we start about 10 A.M. Pass over swampy land and cross several little streams. Then descend into the valley of the Pragchu, clothed thickly with fir and rhododendron. A beautiful, yellowish lichen hangs down from the branches of these trees in the shape of garlands. The Pragchu is a voluminous rushing torrent, somewhat like the Ratong we crossed yesterday. We pass it over two bridges of planks; walk, or ratner jump, over immense boulders along the valley of the Pragchu. Reach Thangme; wet through, as usual.

September 16th.—Since we left Darjeeling we have had very few hours of sunshine. We have never had dry clothes on our back while walking. Distant views we have hardly had any—indeed none, except a transient glimpse of the Nepal snows from Nyatar. W. has been speaking of the weather in not very parliamentary language. He has not yet had an opportunity of using his camera. When it is considered how weight is economized on an expedition like this, the carriage of such a burden without being able to put it to any use is enough to provoke a saint. We had made up our minds to stop at Aulakthang, near the glaciers, until the *weather cleared up. But, lo! the Fates are decidedly favourable to us! The sun is* up in all his glory, and our joy knows no bounds. W. is, of course, busy adjusting his camera.

From Aulakthang (half a mile north of Thangme) we have a superb view of the snowy peaks: Kanchanjinga, towering above all, is right in front of us; Pandim, a mile ahead of us, glorious with the rays of the rising sun; Kabuikang and Tingchingkang, two very fine peaks, just to our right.[1] Pandim[2] has a peculiar head-shaped peak, the nose being turned northward; its southern face is very steep and snowless, and appears (with the help of a binocular) to be formed of the massive gneiss which I have been encountering all along the road from Gamothang. Glaciers from Kabuikang and Tingchingkang appear to come down very low, just a few hundred feet above our level, which is 13,300 feet. Several streams drain these glaciers, and join the Paragchu. The water of all these is muddy.

An immense transverse moraine stands like a wall at the head of the valley. To the naked eye it appears like a mass of white sand; with the help of the binocular, however, very large stones are visible.

There is a hut at Aulakthang with rubble walls for the accommodation of the Llamas from Pemionchi—the first monastery in Sikkim. They visit this place annually about the end of August, or the beginning of September, for the worship of Kanchanjinga. They went away only a few days ago after performing the ceremonies.

At Thangme early this morning there was great excitement in camp. The coolies were pointing in the direction of the hill to the west of the Pragchu, and calling out, "*Baghwa!*" "*Baghwa!*" Looking in the same direction we saw a small cat-like whitish object at a height of some 500 feet or so above us, serenely watching us. With the binocular, it looked the size of a leopard, its front of a white colour. The animal remained quietly sitting for some time as if contemplating the strange scene before him. W.'s shikari—who, by the bye, has been supplying our table with pheasants and other dainties—would not venture after the animal. The Snow Leopard has got longish white hair on the face, legs, &c.; the tail, however, is dark coloured. After sitting quietly for some time, it got up and moved upward. Presently we saw it chasing a raven, which was a very amusing sight.

The valley here, above Thangme, is ◡ shaped, and evidently of glacial origin.

The flora of Aulakthang consists of scrub, rhododendrons, umbellifers, stunted juniper, and similar plants. Fuel has to be got from Thangme.

September 17th.—6 A.M., temperature, 38°; 7 A.M., 40°. Another bright morning. It snowed last night, and the hills on all sides are covered by a sheet of snow.

We have had to send more coolies to Yoksum to get their food. Those that are with us are beginning to complain loudly of having nothing to eat. Fortunately

[1] J. L. Sherwill gives the following description of the scenery of this place: "Immediately on our right out of a long range of perpetually snowclad mountains running parallel with the valley, rose the formidable peak of Pandim, 22,015 feet in height,...... To our rear, winding its course down the broad valley, the hills on either side being covered with dense fir forest, often down to the water's edge, was seen the noisy, foaming Ratong [Pragchu] ..... We were the first European travellers to gaze upon this truly grand scene. Any one desirous of witnessing grandeur of scenery should visit Alutong. However toilsome and comparatively uninteresting he may find the intermediate travelling as far as Jorngi, he will be well repaid by the wild scenery of this locality"—*J. A. S. B. for 1862, p. 471.*

[2] Strictly *Pendi,* which in the Lepcha tongue, means 'a respectable lady.'

there is a sheep pasture close by, whence we procure a couple of sheep and kill them; the meat is distributed amongst the coolies, about a seer falling to the share of each. To them, however, one seer of rice would be more welcome than an equal quantity of meat; and there is not much abatement of their discontent. We are, however, determined to make the best of the spell of glorious weather which we have got. So we take only one tent for ourselves, one pâl for the servants, and just a few necessaries, besides a supply of fuel from Thangme, and start for the glaciers, leaving all impedimenta behind in charge of Dingpun. The killing of the sheep and other preparations take time; so we cannot start before noon.

A short distance north of Aulakthang there are the ruins of two Mendongs. Proceeding a little further we clamber up the wall-like moraine, of which mention has been made already. It appears to be the terminal moraine of more than one glacier—of a very large one sent down by Pandim from the east side, and of others coming from the north—a confused heap of stones of all sizes. This is the lowest limit to which glaciers come down in this valley. On the top of the moraine we are at an elevation of about 13,900 feet, so that its height above the valley must be nearly 500 feet.[1] We see the Prag Chu issuing as a foaming torrent from it a little to our left. The delineation of the head waters of this stream, as given on the survey map, is not correct.

We descend from the moraines into a fine lake with very steep banks on the east and west side; its water deep-blue and clear. Camp by the side of this lake. Elevation 14,100 feet.

On the way and close to our camp occur huge boulders, some 20 feet or more across, mixed with finer *débris*, some as fine as coarse sand. The boulders, &c., are all more or less angular; they are mostly of the massive gneiss, with folia of black mica, which are often wavy. In the gneiss there are veins and lenticular patches of coarsely crystalline granitic rock with or without black crystals (hornblende or schorl). Besides the massive gneiss, there are also fragments of very fine-grained slaty-looking gneiss.

From Migu—our third stage after Phalut—we have been travelling at very high elevations, often above 14,000 feet. Owing to the extremely rarefied condition of the air of such heights, exercise is very fatiguing. But neither W. nor myself have suffered much from the numerous evil effects described by travellers. Once or twice we have had headaches; and on one occasion I had a severe aching pain in another region of the body. But that has been about the extent of our sufferings so far. On the other hand, we have had excellent appetite all along; and, thanks to W.'s arrangements, we have had abundant means of satisfying it. To-day W. has got a severe aching pain in the neck; but we can't say whether it is attributable to the effects of high elevation.[2] The casualties among the servants and coolies have

[1] J. L. Sherwill makes this height to be 1,000 feet. He gives the probable elevation of the moraine to be 15,000 feet. This is too much by at least 1,000 feet.

The elevation, about 14,000 feet, to which glaciers come down in the Lachung valley in East Sikkim, appears to be nearly the same to which they descend on this the west side of Sikkim. (*Hooker, Him. Journ., Vol. II, p. 115.*)

[2] J. S. Sherwill mentions tightness across the back of the head as one of the evil effects of high elevation he suffered from at a little above 14,000 feet. (*J. A. S. B., Vol. XXII, p. 620.*) Bleeding of the nose, distressing symptoms of suffocation, sharp sudden pains in the chest extreme beating of the heart, nausea, &c., are among the other effects noticed.

been rather heavy. Swelling of the feet appears to be the principal complaint. Two of my coolies were disabled thereby and had to be sent back; and Nimdarji (W.'s interpreter) has been left behind at Jongri on account of the same complaint. One of my coolies and one of W.'s servants have got fever and have had to be left behind; the former at Jongri, and the latter at Aulakthang.

September 18th.—The lake we are camped on is bounded on the east side by a steep ridge where rock is *in situ*; on all other sides it is bounded by glacial *débris*. We descended yesterday from the moraine damming it on the south side. To-day we clamber up the moraine on the west side. It is an immense pile of *débris* of all sizes, from 30 feet or more across to very fine sand. It is very hard getting up these, and I clamber up, holding on to stones.

The glacier we are now on is formed by the union of three large glaciers—one coming from Pandim, north of the lake mentioned above, one proceeding from between Kochirangkang, and a peak east of it, which we shall call the Kochirangkang glacier, and the third from between the last-named peak and another (also unnamed) to the north-east of it which shall be named the East Kochirangkang glacier. The moraines are here all jumbled up, without any apparent order; and a wilder and a grander scene of confusion could not well be conceived.

The top of the moraine-bank we are walking on is about a thousand feet above the lake, that is to say, we are now at a height of about 15,000 feet. It snows for a while.

We trudge on northward, keeping to the lateral moraine by the lake. Towards the centre of the glacier there are deep pools with partially frozen water. The banks of these pools are vertical and are crusted over with sand. From a distance the ice is not seen, and we at first took the banks to be formed entirely of sand; but we perceived our mistake later on. *Débris* is continually tumbling down into the pools, making a peculiar "click, click" noise.

At the northern end of the lake, which I shall designate A, we come upon a moraine carried down by a small glacier from Pandim, from under which issues a stream which feeds the lake.

Clambering up this moraine, and proceeding a short distance, we come to another small lake, which we shall call B. It has an outlet under the moraine which we have just passed and which divides it from lake A. The water of lake B is very dirty, and its bed of fine silt.

Proceeding a few hundred yards further north, we reach another lake, which we shall distinguish as C. It has very nearly silted up, several streams lazily meandering through its sandy bed. To the west of this lake is a perpendicular bank of *débris*, apparently the lateral moraine of the East Kochingkang glacier. The side of this moraine-bank facing the lake is clothed with grass and other vegetation. Yet but a few feet beyond this green grassy band there is solid ice which would not support life in any shape. On the south and east sides of the lake also there are vertical banks of glacial *débris*.

As the coolies have mostly to be sent back to Aulakthang partly to get their food which is daily expected to come up from Yoksum, and partly to bring up our fuel for tomorrow, we camp by the side of the lake C (Chemthang on map) at a height of 15,250 feet. Fuel is such a precious commodity here, that in order to economize it we have converted the back portion of our tent (a Kabul pâl 8′ × 8′) into our kitchen. One fire serves to warm us as well as to cook our food; and we have our meals sitting on our cots.

Saw footmarks of wild sheep, which abound here.

September 19th.—A lovely morning. Snowed last night; there is a thin coating of snow on the tents. We are now right amongst the glaciers; moving masses of ice surround us on all sides. Kanchanjinga,[1] Pandim, and the other snowy peaks are gorgeous with the golden rays of the rising sun. The scenery is indescribably fine, grand, and majestic, a parallel to which is probably to be found nowhere else in the world. The silence of the scene is occasionally broken by the deep, thunder-like, rumbling noise of avalanches coming down vertical precipices.

Proceeding northward, we clamber up what looks like the lateral moraine of a fine glacier sent down by a high snowy peak in front of us. It begins to snow after a while, and the view on all sides is enshrouded in misty gloom. We make for the Giuchala pass walking, or rather jumping, over enormous boulders, a method of locomotion which is attended by present inconvenience and prospective danger. As the boulders, &c., are crusted over with snow it is necessary to step very cautiously.

Giuchala literally means 'the locked pass.' The first Llama who came to Sikkim from Thibet is said to have entered by this pass, and he locked it. The name is very appropriate, as no Sikkimite is ever known to have passed this way.

There is a tarn close to the pass where I stop, as I am extremely tired and, a thick veil of mist covering everything, I do not expect to have any view by proceeding farther. W. goes up to the top of the pass and ascertains its height to be 16,430 feet.[2]

W. coming down, we are possessed with curiosity to explore the glacier along the fringe of which we came in the morning. We make for a bare perpendicular scarp which forms the eastern boundary of the glacier. We are now at, or close to, the line of perpetual snow. Above us the gathering ground of the glacier called *névé* is covered by snow and looks beautifully white. But where we are, and below us, the glacier has at the surface a dirty grey colour, which is owing to the finer *débris* carried by it. The *névé* is deeply crevassed longitudinally and transversely into prismatic masses. At places there are bridges of ice, from which hang down beautiful icicles. We walk along the southern edge of the glacier close to the foot of the wall-like "lateral" moraine up which we clambered in the morning. Some huge glacier tables resting upon pedestals of ice are passed—some of them 50 feet or more in diameter. Beneath us we occasionally hear the gurgling of runnels formed by the melting of the ice. A stream issues from the snout of the glacier, which, leaping down over huge boulders, descends into a grassy meadow, and then flows along a rocky channel into the lake we have camped on. Here it divides into several channels, which slowly course their way through the sandy bed of the silted up lake.

The glacier we have just traversed seems to have shrunk, as is evidenced by old grass-clad moraines between it and the lake C. The valley in which the lakes A, B, C, mentioned above lie is directed north—south, and could not have been scooped out by the glaciers coming down from Pandim which run east—west. The glacier which

[1] It should be strictly spelt *Kongchen-jungya*, meaning 'five great snowy peaks.' *Pandim* is strictly *Pendi*, meaning 'a lady.'

[2] The height given by J. L. Sherwill is 18,500 feet, which is too much by about 2,000 feet. (*J. A. S. B. for 1862, p. 473*)

we walked on this morning, in conjunction very likely with the Kochirangkang and the East Kochirangkang glaciers, must have effected the erosion of the valley. All these glaciers appear to have retreated; they must at one time have extended as far southward as Thangme (elevation 12,900 feet). The elevation must have been reduced by denudation since the time of the glacial extension. The retreat northward of the glaciers appears to me to be a consequence of this denudation. As the valley is deepened on the south side, the lowest limit at which the ice of the glaciers remains unmelted is pushed back northward. At the same time the valley is extended northward owing to erosion at the head of the glacier. Above Thangme the valley is ◡ shaped; whereas below it is a deep v-shaped gorge. The difference in the configuration of the valley was very striking as we came up. The shape of the valley appears to me to be the chief point of distinction between glacial and river action in the Himalayas. The peculiar ice-scratchings noticed in glacial *débris* in Europe are either indistinct or absent in the Himalayas; and the size of the boulders is not a safe criterion. I have seen 'boulders' quite as big as any glacial boulders in the Rangit and other Himalayan rivers far below the limit to which glaciers can be reasonably supposed to have extended; and any one who has noticed their impetuosity, especially during the rains, could entertain but little doubt of their capability for transporting such enormous fragments far from the parent rock. It must be remembered that they are transported by rivers not only directly, but also, and, I think, to a greater extent, indirectly by the scouring away of the sand and shingle under them, and thus making them slide downward. The glacial *débris* are more or less angular; but this distinction is soon lost, so soon as they come within the sphere of action of the torrential streams.

There can be no doubt about the retreat of the glaciers northward and the extension of the valley occupied by them in that direction. The nature of the valley near Jongri made me suspect it to have once formed portion of a glacial valley, the glacier probably coming down from Kabru, which has now been reduced by denudation to below the level of perpetual snow.

The lakes A, B, C, are all dammed by moraines. They are only spaces left in the valley between moraines of different glaciers like lake B, or between moraines and steep cliffs like lake A.

Though Kanchanjanga is right in front of us, we have not yet seen the glaciers sent down by that lord of the snowy peaks. We had an idea of crossing by the Giuchala pass into the valley on the other side, to which those glaciers come down, and then returning by the Rinpiram valley to near Thalung. But, W. being pressed for time, the route, an entirely unexplored one, and the difficulties of the journey manifold, we have to abandon the idea. At Giuchala we were just on the limit of perpetual snow. Above us is the gathering ground of the glaciers or the *névé* as it is called, and below the glacier proper.

September 20th.—Another fine morning, temperature at 7 A.M. 39°. Get up the bank of glacial *débris* just west of our tent, W. with his camera of course. The sight that meets our eye is of unparalleled grandeur and sublimity. All the snowy peaks and glaciers surrounding us are well seen. W. has adjusted his camera, and is busy taking views. While he is engaged in that occupation, I walk along the crest of the wall-like lateral moraine bank. From its outer sides, which is clothed, though sparsely, with grass and other vegetation, one would hardly think that it is, on the inner side, in immediate contact with solid ice. The lateral moraine banks of all the glaciers seen from here, stand up like vertical wall-like masses. I took these at first to be lateral moraines, and moraines in similar position have been so called by other travellers;[1] but I much doubt the appropriateness of the expression. The moraine banks in question do not rest *upon* the glaciers, nor have they any ice *in* them. They were, I am inclined to think, originally *terminal* moraines formed of *débris* shot down t the termini of the glaciers before they issued out of the mountain gorges which held them in. With the advance of the glaciers, the moraines have been pushed aside so as *to look like lateral moraines*. From a distance, the moraine banks look like high railway embankments, the outer side invariably covered with green vegetation. The top of the moraine bank I am walking on is very narrow, scarcely a foot or so wide at places. Cracks parallel to it are seen all the way. These are owing to slips which take place on the inner side, probably owing to the melting of the ice. The moraine-banks are about 500 to 800 feet high and nearly vertical. They are comparatively even at the top, and have a rather gentle slope upward, *i.e.* towards the head of the glaciers; the slope seldom exceeds 10°. Their average width at the top is about 3 feet, and one can walk on them without any very serious difficulty. They are composed of *débris* varying in size from huge boulders, 50 feet or so in length, to gravel and sand. As just observed, these *débris* have no ice in them, and have slipped off the glaciers.

As the glacier encroaches into the valley, its terminal moraine will be pushed forward and aside, so as to form banks on either side of the valley. The moraine banks at the sides of the glacier, which I have been describing as lateral moraine-banks, appear to me to have originated in this way.

Enclosed between the straight, wall-like moraine-banks is the main glacier. It presents a very uneven surface, with deep pools, conical mounds of *débris*, and glacier tables of various sizes.[2] The pools appear very deep with the water nearly frozen in them. The banks are nearly vertical, the exposed portion in one pool appearing no less than 100 feet high. The *débris* along the edges of the pools are incessantly tumbling into them.

We have a fine panorama of all the glaciers. Three fair-sized glaciers are seen to come down from Pandim. They all have a general east—west direction. One of them comes down south of lake A, and meets the united Kochirangkang glaciers. It was well seen coming up from Aulakthang. It has a south-western course sloping at an angle of about 15°. North of lake A, and south of lake B, another glacier

[1] Speaking of a glacier in East Nepal, Hooker says, It "was marked by two waving parallel lines of lateral moraines, which formed, as it were, a vast, raised gutter, or channel."—(*Hooker, Him. Journ., Vol. I, p. 260.*)

[2] For the origin of these cones and glacier tables, see Tyndall's "Glaciers of the Alps," p. 265, &c. They are thus accounted for by Forbes (Occasional Papers, 241): "As the glacier surface wastes by the action of the sun and rain, these heaps are brought to the surface, or rather the general surface is depressed to their level. If the earthy mass be considerable, the ice beneath is protected from the radiation of the sun and from the violent washing of the rain; it at length protrudes above the general level of the glacier, and finally forms a cone which *appears* to be entirely composed of gravel, but is in fact ice at the heart, with merely a protecting cover of earthy matter......The similar protective action of large stones detached from the moraines and lying on the surface of the ice often produces the striking phenomenon of glacier tables."

comes down from Pandim and joins the united Kochirangkang glaciers. Between the lakes B and C a third glacier comes down from Pandim.

The Kochirangkang is a very fine one. It curves southward as it issues out of the rocky gorge and joins the east Kochirangkang glacier (also a very fine one) at an acute angle. The outer sides of the lateral moraine-banks of both of these glaciers are covered with vegetation.

The united Pandim and Kochirangkang glaciers move southward; and as far as the eye can stretch in that direction, nothing but a wild confusion of moraines and ice-pools is seen.

The glacial *débris* are mostly of massive gneiss with or without veins, of a white granitic rock, in which latter no black mica occurs, but which frequently contains schorl. The gneiss is usually of a whitish colour, but some with a reddish tinge is also seen. It presents indistinct bedding when seen *in situ*, as near Giuchala. The beds are very thick, about 10 feet, and they are inclined north-eastward at an angle of not more than 30°. Some fine-grained gneiss and mica schist are also noticed among the *débris*; but they were nowhere seen *in situ*. Blocks of granitic rock also occur. This rock may be of intrusive origin. I have had but slight opportunity of examining rock *in situ* here. But what I saw about Timbu lake, and between it and Gamothang, strengthens this conviction in my mind.

The massive character, low dip, absence of contortion, and the presence of granitic veins are the chief points of distinction between the gneiss we have been encountering from near Gamothang, and that developed about Darjeeling.

I would fain have lingered here and explored the glaciers and the surrounding country for some time longer; but for various reasons I could not do this, and after breakfast we got ready to march back to Aulakthang.

On our way back we noticed a small glacier coming down from a peak marked as 'Kabru E. P.' on map.

September 21st.—Between Aulakthang and Thangme several moraine banks are passed. These may either be the terminal moraines of the Pandim-Kabru-Kochirangkang glaciers which have retreated northward, or the lateral moraines of the glaciers east of Aulakthang, which appear to have retreated eastward. Below Thangme the valley of the Pragchu contracts considerably, and it flows through a deep gorge with precipitous sides contrasting strikingly with the glacial valley above Thangme, which is broad and ◡ shaped. The ascent from the Pragchu is rather steep. Reach Jongri at 2 P.M.

September 22nd.—From Jongri we get down to the Pragchu. The descent is very steep, and the path below Bakhom extremely slippery. Bakhom is a halting stage, there being water and camping-place. But as we reached that place rather early, and as some of the coolies had gone on in advance, we make up our minds to push on in the chance of finding a camping-place further on. Crossing the Pragchu over a frail, shaky bridge, we have some uphill work. We trudge on and on, but fail to find a place to put up an $8' \times 8'$ tent, the flank of the ridge we are walking along (which forms one side of the gorge through which the Pragchu flows) is so precipitous. It is a very noble forest we are passing through, with stately oaks, chestnuts, yews, &c. But physical sufferings have well nigh reached the limit of endurance, and I walk on almost mechanically, insensible to the surrounding charms. Besides, the path is so bad, and the consequences of a false step so serious, that one's attention is engrossed by it. It gets dark. Fortunately there is a lantern at hand. With its dim light we walk on, stepping cautiously, get down some awfully steep precipices, where one false step would hurl one down hundreds of feet. W. and some of the coolies have gone on ahead. At last, to my intense delight, I see our camp fire at a short distance, and a man with a light kindly sent by W. comes to meet me. After 8 P.M. I reach our camp, which is called Nibi, after a pair of large caves, one of which affords shelter to W., myself, Dingpun, and a good many others, and the other is taken possession of by the majority of the coolies. There is no room for a tent here. The caves are formed by huge blocks of overhanging gneiss which is the rock met with all the way from Jongri. They are not at all uncomfortable.

September 23rd.—Path extremely narrow, there is scarcely foothold at places; one or two bits very steep. I have sometimes to crawl on all fours, and sometimes to hang down holding on to creepers. Path better near Yoksum. Meet with cultivation for the first time since leaving Darjeeling. Smiling fields of millet delight the eye. A very sad accident occurred on the way to one of W.'s coolies. The poor man was crossing a furious torrent over the usual frail bridge[1] customary in these parts, made of a trunk thrown across, when he lost his balance and fell with the load on his back. He was of course instantly carried far, far away and probably smashed to pieces. W., who had crossed before, was watching him, and the sight was heart-rending. He immediately got the bridge in order for the coolies who were behind.

Just on the outskirts of the village I find the headman waiting with a *chunga*[2] full of murwa. We have had a comparatively short but rather hot march, and the drink refreshes me. Our tents not having arrived, we take shelter in the house of a Bhoteea. It is, as usual, two-storied. The lower floor is reserved for pigs; the upper consists of a large room, fairly clean, from the ceiling of which hang cobs of thickly packed Indian corn, some of which are beautifully red.

Yoksum is the northernmost inhabited place on this side of Sikkim. It literally means 'three Llamas', and derives its name "from having been the earliest residence of three Llamas of great influence who were the means of introducing the first Thibetan sovereign into the country."[3] This was about 300 years ago. The first king was named Dhingso Nam Gyal. The present king, I am informed, is ninth in descent from him. This would give an average of thirty years steady reign. The place has a very ancient appearance; ruins of *Chaits*[4] and *Mendongs*[5] abound.

[1] These bridges, which are meant for men to cross over, are not made with that care which is given to those intended for sheep, such as we found between Gamothong and Aulakthang.

[2] A *chunga* is a hollow joint of bamboo. The murwa is drunk through a fine bamboo tube.

[3] Hooker's Him. Journ., Vol. I, p. 335.

[4] *Chait* is also called *Choten* (*cho*-sacrifica, 'a place of sacrifice or worship'). It would appear to be corrupted from Sanskrit *Chaitya*. *Chaitya*, however, means 'an assembly hall or church,' and is, as a rule, excavated; whereas, *Chait* is 'a small, solid, conically-shaped structure built in memory of the dead.'

[5] *Mendong* ('place of *mani* or jewels') is also called *mani*, and is a wall-like structure of holy inscribed stones.

"Beautiful lanes and paths wind everywhere over the gentle slopes, and through the copsewood that has replaced the timber trees of a former period."[1]

Yoksum is a curious piece of undulating ground enclosed by high mountains. Barring its low elevation, which is not more than 5,500 feet, it resembles Jongri or Aulakthang closely. There are several pools, one of which is very romantically situated. I failed, however, to find any evidence of glacial erosion.

The paper plant (*Daphne*) grows here in abundance. It is a small shrub from the bark of which the paper in universal use in Sikkim is made.

September 24th.—Halt. A very fine morning. We have a peep at the snows through the dark, deep, gorge we passed yesterday and the day before. The monastery of Dubdi,[2] the oldest in Sikkim, perched on the top of a hill one thousand feet above us, amidst tall stately weeping cypresses, looks very fine. We visit the monastery in the afternoon. There are two *Gumpas*,[3] one of which, the older, has a neglected look about it. The main Gumpa is a comparatively recent structure; it is two-storied. We are conducted to seats prepared for us near the altar. Roasted *bhutta*, rice, eggs, &c., and the eternal murwa are placed before us.

The Gumpa is a wooden structure. The walls are painted all over by members of the holy fraternity. Some of the paintings, however, are not very edifying or holy sights, at least to the uninitiated spectator.

Grand view from here of the surrounding country. The monasteries of Ketsuperi, Mali, Pemionchi, &c., are well seen. Perched on hill tops their situation is well suited for monastic life. I am not, however, particularly impressed with the specimens of the brotherhood before me. Some of them look little better than coolies and appear to be quite as ignorant. But for their shaven heads they could be scarcely distinguished.

September 25th.—Leave Yoksum. On the way halt at Inthang, where I find W., Dingpun and others deep in a carouse over murwa, and I join them. Here I learn how this delicious beverage is made. It is chiefly prepared from millet, which is gathered and placed under some spring or *jhora*, so that it may be thoroughly cleaned. It is afterwards boiled until the grains are quite soft, and then spread over mats for a few days, when the stuff gets fermented. It is then ready for the *chunga*. Some *masala* consisting of ground rice and ginger is put in, but that is only to make the drink pungent and give flavour to it. Murwa serves as food and drink to, I may say, the entire population of Sikkim. When well made it is wholesome and refreshing, but sometimes, though rarely, the stuff that is given you is execrable.

Cross the Ratong (formed by the junction of the Pragchu and the Kamzar) over a good cane bridge. Halt at Tingling, just below Ketsuperi. We have a very fine day. Narsing is seen in all his glory.

September 26th.—Going down to the Risu and beyond, the dip of the gneiss for some distance is seen to be north-western (strike N.E.—S.W.). Some highly garnetiferous gneiss is seen in the Risu. Beyond the Risu, on the way to Pemionchi, the gneiss becomes highly micaceous, looks almost like mica schist. By the Rangbi,

[1] Hooker, *op. cit.*, p. 336.

[2] Literally 'place of worship.' There are two monasteries here. The older one, which was built by the three Llamas already mentioned, has now a rather deserted look about it.

[3] Gumpa is apparently a corruption of the Sanskrit *Gumfa*, which means 'a cave,' in which case it would be the equivalent of *Chaitya*.

the strike of the gneiss is nearly N.—S. The ascent from the Rangbi to the Pemionchi monastery is rather steep. Fortunately the Llamas have sent a couple of ponies for us, and though the path is very bad, they help us to get up.

Pemionchi [1] has a very commanding situation. We have a fine view of Darjeeling, Tendong, &c., from our camp, which is just below the nonastery, near some Chaits. We walk along a spacious lane (evidently at one time a made road) through a fine jungle abounding in pheasants, green pigeons, &c., and reach a most romantic place called Rabdenchi.[2] It was at one time the seat of the Sikkim Rajas before the invasion of the Gurkhas in 1814. We get up to a platform built of stone, and have an excellent view of the Snowy Range. Any one visiting Pemionchi should not miss this place.

There is a large two-storied thatched building here which at one time sheltered no less a personage than the Raja of Sikkim. It is still kept up in fairly good repair. There were pigs—the delight of the Sikkimites—running about the place, and I noticed two or three shadowy figures running away in a hurry as we approached. Happening to want a light for my cigar, I went to the building, got up to the upper floor by a ladder, and called out from outside, but received no answer. I shouted to the top of my voice; still no answer. I began to doubt if what I saw might not be an illusion, but the squeaking omnivores were a sure indication of the proximity of human beings, and I entered the building to solve the mystery. I found myself in a very spacious but dark room, divided into compartments by wooden screens. There was nobody in the compartment I was in; and the whole place seemed to be wrapped in gloom and silence. I went into another compartment, and there found an altar, sitting in front of which was a holy brother deep in meditation, with a *chunga* full of murwa by him. I could hear another holy gentleman in the next compartment, apparently saying his prayers. I asked for a light. No answer, but a wave of the hand motioning me to be off. I stood for a while and the Llama produced a box of matches from the folds of his garment. I learnt afterwards that these members of the sacred order are supposed to spend their time in devotion. Evidently they were engaged in anything but their rightful occupation when we came.

The Llamas of Pemionchi are called 'Tasung' Llamas, which means that they lead a specially pure life, strictly keeping their vow of celibacy. All Llamas have to take this vow. But from the number of the gentler sex seen about the monasteries, and from the striking resemblance which some notice in the children hanging about them to the shaven Fathers, it is much to be doubted whether the vow is kept at all, at least by the great majority.[3] The Tasung Llamas of Pemionchi are supposed to be among the purer minority.

I must say one is rather apt to be disappointed with the Llamas here. The life which by far the greatest majority of them lead is the very reverse of what one would expect from that sacred order.[4] In violation, I believe, of one of the cardinal prin-

[1] *Pema* 'lotus.' *Pemionchi*, literally, 'the heart of the lotus.' It is called *Sangchhen* = 'great sacred.'

[2] Literally 'the best palace.'

[3] This, however, is the 'red-cap' order *Yungmapa*, who are not as strict in their professions as the 'yellow cap' order, *Gellupa*. There are but few Llamas of the latter order in Sikkim.

[4] I learn that the vow is strictly kept to the letter by all the Llamas. The holy fathers and brothers *never marry*. There are a few Llamas (the Raja of Sikkim among them), who lead very pure lives.

ciples of Buddhism, they all partake of meat (beef, pork, &c.). Those who are very scrupulous do not take fresh meat, and avoid it on certain days. I have already said how they keep their vow of celibacy. They all drink murwa of course, and swilling monks are very far from rare. Of course whatever learning there is in the country, it is in their possession. I doubt if any schools or libraries are to be found outside the walls of the monasteries. But the monks impressed me as much by their knowledge as by their sanctity. I asked certain questions from the history of Buddha; but from the first Llama of the first monastery in Sikkim, I got anything but satisfactory answers. It is possible for me to have misunderstood them however, as I am ignorant of Thibetan, and our conversation had to be carried on through an interpreter.

September 27th.—Halt. A lovely morning. Magnificent view of Darjeeling on one side, and of the Snowy Range on the other.

A special service is held in the monastery at W.'s request. We go up to the monastery at 8, and are received at the entrance by the Llamas in procession, flags flying, trumpets blowing, &c. We go round the Gumpa once and then enter a very large hall. We are seated on a bench on one side, the never failing murwa before us, and, in addition, a cup of buttered tea. In front of the altar are seated in two long rows the Llamas and some boys[1] (apprentice Llamas). The chief Llama occupies a raised seat at the head of one row, close to the altar. At a given signal, all with one voice, pray in honour of the tea twice, and then we drink tea, each of the Llamas and their pupils being provided with a wooden cup similar to ours. Buttered tea, like murwa, is in universal use in Sikkim, and does not taste bad if the butter is not rancid. After tea there is more chanting of hymns, accompanied by blowing of trumpets, &c.

The service over, we are conducted upstairs, where in one room we are shown a rather rich collection of books. These all come from Thibet. We are also shown some robes of China silk, rosaries, masks, &c. In another room we see an altar, and a number of books in cases; fail to obtain any reliable information about the exact contents of the books. I learn however, that the books are divided into two classes—I., Tenjur, 225 volumes, each containing about 500 leaves, which cost at Tashee Lumpa R1,500; II., Kajur (from *ka* = 'order'), a collection of Buddha's orders, 100 volumes, which were purchased at Tashee Lumpa for R1,000.

We are then conducted to the third floor, which contains the kitchen of the holy fraternity. The Llamas are all Bhoteeas,[2] *i. e.* of Thibetan origin, though more or less remote, as a rule. The Lepchas, who appear to be the aborigines of Sikkim, are seldom admitted to the order, though they are Buddhists. The monastery of Sangachelling is said to have Lepcha Llamas.

Silvery glossy mica schists occur about Pemionchi; usual strike N.W.—S.E., dip about 30° or so S. W.

In the afternoon go down to Keysir Mendong, supposed to be the largest *mendong* in Sikkim. The path (which appears to be a made road) is practicable for ponies all the way. Just above the Mendong there is a rather fine section exposed

[1] These boys are employed in various capacities—to fetch water, fuel, &c.

[2] Bhot is the name by which Thibet is known to the people. People from Bhutan are also called Bhutias. But their number is small and, like the Lepchas, they are not allowed to become Llamas as a rule.

by the roadside. The rock is chiefly mica schist, with interbedded quartzite. We are now evidently on the Dalings, the gneiss having disappeared entirely.

The monastery of Pemionchi is the richest, largest and most important in Sikkim. It enjoys the revenues of the adjacent villages. The head Llama is a member of the Sikkim Administrative Council.

September 28th.—Walk through a charming avenue of stately oaks, chestnuts &c., along the crest of the Pemionchi ridge, and then get down to Yangtung Kaji's,[1] village. The old Kaji is dead. His son, a very civil young man, having taken the vows of a Llama, is debarred from succeeding to his father's title. He and his uncle, the present Kaji, receive us and take us inside the house. It is two-storied, as usual. The lower floor is reserved for cattle and pigs. On the upper floor there are three decent-sized rooms. In one of these is an altar, with the usual Buddhist figures and paraphernalia of Llama worship, such as trumpets, &c. This is the best room in the house, the wood-work being richly carved and painted over, though not very artistically. We are seated here, the never failing *murwa* before us. The trumpets, of which there are a couple, are said to have come from Thibet and cost R100 each. The influence which Thibet has hitherto had on Sikkim is evidenced by the high value set upon all Thibetan articles. If you inquire about any article of value, you will be told it comes from Thibet. No doubt, precious articles, such as gold, turquoise, &c., do come from there; but it is possible that such things as the trumpets before us (which are made of copper and brass) may have been manufactured in Nepal. However, being supposed to be of Thibetan make, their price is double what it should be.

Considering the position which a Kaji occupies in Sikkim, it is rather strange hat there are no old weapons in the house, except a rusty ancient muzzle-loader. This shows how peace-loving the Sikkimites are.

The room next to the one where we were received is the largest and best in the house; but, strange to say, that it is used as a kitchen. The third room, which is of much smaller dimensions, is used as a sleeping-room.

I need hardly say that there is no zenana or caste system in Sikkim—I mean among the Bhoteeas and Lepchas. The Limbus and Hindu Paharias from Napal, who have settled in large numbers, especially in the Kulhait valley, where we now are, observe caste.

The widow of the late Kaji, a dignified-looking old lady, comes in our presence and talks to us as freely as any English lady would.

There is no social restriction upon a widow's uniting herself with any body she chooses; though such union, I understand, is not considered to be quite so orthodox as marriage. The marriage-tie in Sikkim is easily loosened. A wife leaving her husband has to pay a fine of R60, and a husband deserting his partner is mulcted at a slightly higher figure, R90. There is no fixed age for marriage; but it usually takes place after the bride and bridegroom have attained maturity. The bridegroom has to spend about three years in courting before the marriage is consummated.

Meet with gneiss a little to the west of Yangtang Kaji's village, dipping westward. It appears to rest on the mica schists (Dalings), with perfect conformity, as it does elsewhere. Camp at Lingcham; Sangachelling monastery in view just above us.

[1] The Kaji is a very important functionary in Sikkim. He is a collector of revenue and chief magistrate within his Kajiship. The post is hereditary.

The direct route from Pemionchi to Darjeeling, whither we are bound, is *viâ* Rinchinpong; but we have taken this somewhat circuitous route partly to see the western portion of the country about Dharamdin, and partly to avoid the leech-infested hot valleys which we would have had to traverse if we went by Rinchinpong.

September 29th.—About a mile west of Lingcham there is a fairly wooded ravine with two waterfalls; one of these exposes a fine section. Mica schists, with black mica of a different type from those which occur about Pemionchi, interbedded with micaceous quartzites and gneiss, occur, dipping W 10° N. There can be no doubt that these rocks belong to the gneiss series (Darjeeling gneiss of Mallet). They continue all the way to Hi, where we camp at an elevation of 5,100 feet. The Kulhait, a fine foaming torrent, is crossed over a rather good cane bridge, but a streamlet running into it is bridged by a trunk with notches cut into it, a very slippery concern; and one of my coolies had a very narrow escape. He fell down, but was immediately rescued.

September 30th.—From Hi we wanted to take the path marked on the survey map to Singriong; but we were told that the path had not been in use for some time, and was so overgrown with jungle that it was not discernible. However, orders went forth from the Political Agent yesterday that the path was to be cleared, and this morning we set out in the direction of Singriong. Our guides, however, take us a long way out of the track; in fact, nearly up to the top of Helu peak (9,370 feet). The path is the driest we have ever traversed—not a drop of drinkable water was to be had anywhere; and it is quite dark before we reach Singriong, famished and thirsty; in fact, quite done up. W. had preceded me, and he has taken quarters in the house of a Nepali settler, Serpa Bhoteea by caste, our tents not having arrived as yet. As I have said above, the Sikkimites proper (Lepchas and Bhoteeas) observe no caste. We have hitherto been cordially welcomed to the hearth of every home we visited. Such outward expressions of goodwill as *chungas* of murwa have never been wanting. The Lepchas and Bhoteeas would eat anything you offer them, and are altogether very sociable companions. Their marriage customs are different from those of the Hindus. Early marriage is unknown; and a kind of courtship takes place before marriage. But just now we are amongst Limbus and Hindus from Nepal, usually known as Paharias. They delight in pork, just as much as the Lepchas and the Bhoteeas do, and pigs form quite as integral a portion of the family of the former as they do of the latter, still they are Hindus, and are hedged in by barriers of caste, like other Hindus. W. not knowing the religious persuasion of his host went inside the house, but was told to come outside. He did so and was accommodated in an open hut, where, of course, he was comfortable enough, sitting by a roaring fire. The Sikkimite Lepchas and Bhoteeas, who eat beef and pork as much as the Christians do, and my Lepcha cook, who is a convert to Christianity, are of course freely admitted into the house. Here the barrier of caste is, as usual, evidently interposed against colour and foreign costume!

October 1st.—This morning there was quite a scene in the house of our worthy host at Singriong. As we got out of our tent (wherein we sheltered ourselves at night) we found a number of earthen pots had been put out in the yard where our tent was pitched. The pots contained fermented *bhutta*,[1] ready for the *chunga*,

[1] Amongst the Paharias *murwa* is usually prepared from *bhutta* ('Indian corn').

butter, and other things. The mistress of the house was jabbering away deploring the heavy loss she has sustained. The things were represented to us to have been put out on account of W. entering the house last evening. They did not, however, represent the entire loss, for the house was to be re-thatched; otherwise, it would not be fit to live in again. So there was a heavy bill for damages. We argued. We pointed out that if a Lepcha Christian could enter the house without defiling it, why should W.'s entrance entail such serious consequences? But, of course, all to no avail. The bill for damages was then paid by W.

The Nepalese settlers, who form by far the greater majority of the population in these parts, are more industrious and more intelligent than the Lepchas, who are an easy-going, merry-hearted people. In the struggle for existence the latter are sure to give way to the former.

Going to Dharamdin we pass through some cardamom plantations in the valley of the Rangyang, a feeder of the Rummam. Cardamom is the most paying crop in Sikkim. It thrives best in the valleys of these mountain torrents. A portion of their water is diverted for irrigating the cardamom fields. Just now the cardamom is being gathered and dried over big fires. Fresh from the plant, it has a slightly acid and very pleasant taste.

Cross the Rangyang over a substantial bridge made of planks. At Dharamdin there is gneiss, somewhat massive, but easily recognizable as the Darjeeling gneiss. The dip here is western, as at Lingcham.

A fine, long stretch of green paddy fields is presented to our view at Dharamdin; it is the best piece of cultivation we have seen as yet. The fields are terraced and well irrigated. The Kulhait and the Rummam valleys are probably the best cultivated in Sikkim.

There is a Kaji at Dharamdin, who is called Dallam Kaji, though no such place as Dallam is in existence—at least anywhere about here. The Kaji, a very decent young man, meets us with the usual presents of *murwa*. We camp above the rice fields, close to a ruined *mendong*.

October 2nd.—Re-crossing the Rangyang, we get up to the ridge on the east side of that stream, and walk to Seriong. This being the Dussera festival (Doorga Pooja of Bengal) the people of the villages (the Hindu Paharias or Nepalese settlers) are enjoying a holiday, and the villagers, who have come to meet us, are all in their gala dress, and mostly appear to have had a 'drop' too much. A right royal reception is accorded us, or rather to W., he being the 'Bara Sahib' of Sikkim. This valley being highly populous, and the people all well-to-do, murwa and such presents as milk and eggs have been waiting nearly every two or three miles of our way. To-day a regular procession is formed with drums. The drummers would not stop on any account; so we make up our minds to undergo the infliction, keeping at as respectable a distance from them as possible.

The headmen of Seriong, of whom there are a number, are very well to do. The assessment hitherto has been *very* light. Indeed, throughout Sikkim the rents which the cultivators pay are very low and are partly paid in kind.[1] The revenue which the Raja has hitherto derived from land—indeed from all sources—has been very low, probably not more than Rs. 10,000 a year, if even so much. This does not

[1] The Lepchas and Bhoteeas pay their dues to the State only in kind, about a twentieth part only of their crops. The Nepali settlers usually pay in coin.

of course, represent the entire amount exacted from the ryots by the Kajis. But, even allowing for the perquisites and emoluments of the latter, the rent which the ryot has been paying must be very low.

There is no police in Sikkim: no regular magistracy—no jail. If any person commits any very heinous crime, such as murder, he is apprehended by the village headman with the help of the villagers and taken to the Darbár. If his guilt is proved, he is sent across the frontier into Nepal, and never allowed to return. This kind of banishment is the highest sentence known in Sikkim, and there appears to be seldom any occasion for its enforcement. For lighter offences flogging is resorted to. To-day W. has to exercise his magisterial authority. Close to our camp at Seriong, there is a shop kept by a Marwari. The Marwaris, by the bye, are penetrating into Sikkim, now that the country has been taken under British protection. They are good traders, and in their strictly trading capacity they deserve every encouragement. But, as they are great usurers, their settlement in large numbers cannot but be regarded with apprehension. Throughout Sikkim the people are now very happy in their own way; but woe betide them if they once get into the clutches of the money-lending Marwaris! W., who identifies himself with the interests of the people, says he will protect the people against the usurers. It is to be hoped he may.

To return from this digression. The shop mentioned above being in a very populous part of Sikkim, carries on a good business, and is the resort of various characters, which from the proximity of this place to Darjeeling must comprise not a few vagabonds. Two of these got hold of Nimdarji (W.'s interpreter) without any the least provocation, and hugged and shoved him most unceremoniously, not without detriment to various parts of his body. Nimdarji comes with a most rueful countenance and relates the story. We repair to the shop. W. holds an enquiry. Both of the culprits appear to be quite drunk. One of them was proved guilty by the unanimous testimony of eye-witnesses, including the shopkeeper, and he is sentenced by W. to flogging and confinement for the night. The flogging is done in our presence.

East of Seriong fine dip-slopes are seen in the gneiss.

October 3rd.—East of Seriong, at the monastery of Nobling, come upon mica schists exactly similar to those met with about Pemionchi. There can be little doubt that they are Dalings. They apparently pass under the gneiss with perfect conformity, both dipping westward, as they do west of Pemionchi. There are in these Dalings highly carbonaceous shales at places, as by the Rummam, near Gok.

We halt just below Nobling, near a chait, to have a pull at the murwa, which has been brought for us by the Dewan's people from Chakang, whither we are bound to-day.

Chakang is the seat of a Sikkimite nobleman of, I believe, a higher rank than the Kaji, named Parvu Dewan. He is away. His son receives us and takes us into his house, which is of the same type as that of the Yaugtang Kaji. We are taken into a room provided with an altar, and are treated to murwa, &c. Camp close to a school which has been established by Mr. Sutherland, of the Kalimpong Scotch Mission. This is the first attempt to spread education in Sikkim. Till now education was confined within the walls of monasteries. It was very exclusive, being imparted only to a few Bhoteea boys apprenticed to the Llamas, and was extremely narrow in its scope.

Visit the Ratho copper mines in the afternoon. They occur in the valley of the Ratho, a tributary of the great Rangit. The ore appeared rather poor. I had, however, little time for examination.

W. entertains the Dewan's wife at tea.

October 4th.—This morning the wife of the Dewan, a Lepcha, with several female attendants comes to bid farewell. We are now on the border between Sikkim and Darjeeling district. The sal trees here are cut down to be made into charcoal for tea-gardens in the Darjeeling district. Hitherto the trees were recklessly cut down, and the revenue they yielded to the State was merely nominal. Under the new *régime*, however, the operation of the contractor's axe is to be restricted, and a proper price is to be paid for the trees felled. So W. goes to the sal jungles below Chakang, accompanied by a Paharia contractor, to inspect the forests, while I go down to Singla bazar. The path from Chakang down to the Rummam, a descent of over 3,500 feet, is in excellent condition, and could be ridden all the way.

In the Rummam, Daling quartzites are seen with a high dip, very nearly vertical. The Rummam is crossed before its junction with the great Rangit by a substantial cane bridge. The rocks *in situ* by the side of the river are Daling quartzites and schists, but enormous masses of gneiss are found along the banks of the river, which must have been carried from some distance. I have already had something to say about the competency of such rivers as the Rangit and the Tista to transport these huge masses. Reach Darjeeling in the evening.

The Salts *of the* Sambhar Lake *in* Rajputana, *and of the* Saline Efflorescence *called* 'Reh' *from* Aligarh *in the* N. W. Provinces; *by* H. WARTH, PH. D., *Geological Survey of India.*

After having ascertained that the Sambhar Salt Lake contains borax (see Vol. XXII of the Records, Part 4, 1889), I was curious to find out if reh from the N. W. Provinces would not perhaps also contain this substance. I obtained some reh from Aligarh, and found that there is also borax present in this efflorescence. But, besides the borax, I was also able to prove iodine and bromine, which two are also present in the Sambhar lake.

The sample of reh was very earthy. It yielded only 6·6 per cent. of dried extract. This extract consisted almost entirely of sodium carbonate, sulphate and chloride being present in lesser proportion.

According to roughly approximate colour-tests, the dry extract of the reh contains—

0·1 per cent. of crystallized borax;

0·1 per cent. of iodide, and somewhat less bromide than iodide.

The Sambhar Lake salt mixture gave more bromide than iodide.

I made a concentrated mixture of foreign salts by fractional crystallization of 5lb. of mother liquor from the Sambhar salt manufacture. In this, I was able to determine the potassium also quantitatively, Doubling my result on account of the loss which attended the crystallization, I make out about 0·04 per cent. of potassium carbonate in the saline residue of the ordinary lake brine.

I also examined the crusts (tapris) from the lake, which consist of about equal portions of sodium chloride, sulphate and carbonate, and found that *on an average* they did not contain more borax than the ordinary Lake brine residue.

The residue of the ordinary brine of the Sambhar lake has, according to the foregoing, compared with the reh extract, more chloride, sulphate and biborate, less carbonate, less iodide; whilst the bromide is about the same in both.

The occurrence of no less than six different salts in both the Sambhar lake and the reh, is a strong argument in favour of a similar origin of the Sambhar lake and the reh of the N. W. Provinces. They must both be considered as accumulations of saline matter derived from the drainage, through evaporation. At the same time, we may still allow the possibility of a special supply of chloride of sodium from some unknown or vanished rock-salt deposit to account for the excess of chloride in the Sambhar lake.

Analysis *of* Dolomite *from the* Salt Range, *Panjab*; *by* H. WARTH, PH.D., *Geological Survey of India.*

The Magnesian Sandstone of the Eastern Salt Range was first so called by Dr. Fleming. He analyzed a specimen from Jogi Tilla with the following results (see Wynne's Salt Range Memoir, page 88):—

Quartz sand	28·0
Iron and alumina	7·3
Carbonate of lime	32·9
Carbonate of magnesia	31·2
Loss	0·6
TOTAL	100·0

Mr. Wynne assumed that the analyzed specimen was exceptionally calcareous and magnesian, and retained the name of Magnesian Sandstone.

To remove the doubts which I had on the matter, I collected 40 specimens of the rock from Kheorah and the neighbourhood, taking care to get well over the outcrop. I pounded and mixed equal weights of these 40 specimens, and I used for analysis the mixture which represented a fair average of the whole rock. The result was as follows:—

Portion soluble in acid.

Calcium carbonate	44·6
Magnesium carbonate	30·7
Manganese carbonate	0·2
Ferrous carbonate	2·1
Ferric oxide	0·9
Alumina	0·6

Portion insoluble in acid.

Silica	16·0
Alumina with ferric oxide	2·9
Calcium oxide, etc., by difference	1·7
TOTAL	99·6

The rock contains 77·6 per cent. of carbonates, and only 16·0 per cent. of silica. A portion of this silica is really present as clay in combination with alumina, and a further portion forms other silicates, so that the free silica, or sand, will not exceed 12 per cent. A rock which contains at most 12 per cent. of sand cannot be called a sandstone.

It is therefore desirable that the name 'Magnesian Sandstone' should be replaced by another, such as 'Magnesian Limestone,' 'Nodular Dolomite,' or the like.

Mr. Wynne refers more than once to the nodules which fill portions of the dolomite. They are lenticular, and somewhat concentrical. The mean length of the nodules is one inch, and the thickness about a quarter-inch. Layers with these nodules are nowhere entirely absent in this rock. I found them still in the Nilawan near Nurpur, where the rock is just thinning out to the westward. According to Wynne, the maximum thickness of the rock is 300 feet. Immense quantities of the *débris* of the rock are also scattered over the sides and the base of the Eastern Salt Range. The exposed surface of the rock, and of its *débris*, is always light-brown, or fawn coloured. This colouring is produced by the dissolving action of the rain and by oxidation. The water removes the carbonates of lime and of magnesia, and the coloured oxides of iron and of manganese remain on the surface. The fresh fracture of the rock is usually grey, or even bluish, but the brown-coating makes it look from a distance like a ferruginous sandstone.

The rock is well known as a good durable building stone. It dresses almost as well as a sandstone, and yet is far more durable than, for instance, the purple sandstone of the Salt Range. I have seen it last well in saline ground, where the purple sandstone gave way. As the railway may cause a more extensive use of the stone for buildings, it is so much more desirable that its composition should be known.

Since writing the above I had an opportnnity of examining the typical specimens of the Dolomitic Sandstone Group, in the Museum of the Geological Survey, which were collected during his survey by Mr. Wynne. The specimens are—

No. 80.—White sandy dolomite: A. B. Wynne.

No. 81.—White dolomitic rock, oolitic: A. B. Wynne.

No. 84.—Magnesian Sandstone: A. B. Wynne.

A rough analysis gave the following results:—

	No. 80	81	84
Silica and other insoluble residue	5·0	6·0	61·6
Alumina, oxide of iron, trace of silica	1·9	1·7	1·4
Calcium carbonate	51·6	51·0	20·6
Balance, chiefly Magnesium carbonate	41·5	41·3	16·4
	100·0	100·0	100·0

The two first specimens are as pure dolomites as one could wish. The third specimen contains 61·6 insoluble matter, and may only just be called a sandstone because it is a little more than half-sand.

It follows, therefore, that the group contains a layer or layers which may be called highly dolomitic sandstone, but other parts of the group are out and out dolomite. It is now a question which kind predominates, and I do not hesitate to say that the latter must predominate and are forming the chief bulk of the group, and more particularly of those outcrops which form the exposed crests of the Eastern Salt Range. The appellation of Dolomite would, therefore, still seem more correct for the whole group than that of Sandstone.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 6.—Ending 31st January 1891.

Director's Office, Calcutta, 31st January 1891.

The staff of the Survey is at present disposed in the following parties:—

Madras Party.—R. B. Foote, F.G.S., Senior Superintendent, Cuddapah District.

Burma Party.—Theo. W. Hughes Hughes, A.R.S.M., Superintendent, Tenasserim.
Fritz Noetling, Ph.D., Palæontologist, Upper Burma.
H. Warth, Ph.D., Tenasserim.

Punjab Party.—C. L. Griesbach, C.I.E., Superintendent, Miranzai Expedition.
C. S. Middlemiss, B.A., 2nd Grade Deputy Superintendent, Hazara.

Baluchistan Party.—R. D. Oldham, A.R.S.M., 1st Grade Deputy Superintendent.
Sub-Assistant Hira Lal.
Sub-Assistant Kishen Singh.

Darjiling and Sikkim.—P. N. Bose, B.Sc., 2nd Grade Deputy Superintendent.

Bengal Coal-Fields.—T. D. La Touche, B.A., 2nd Grade Deputy Superintendent, Daltongunj.

Assam.—P. N. Datta, B.Sc., Assistant Superintendent.

Head-Quarters, Calcutta.—The Director; T. H. Holland, A.R.C.S., Assistant Superintendent, Museum and Laborator

Mr. Hughes has resumed operations at the tin exploitation in Tenasserim. Dr. Warth, on joining the Department, has been placed with Mr. Hughes.

Mr. Griesbach left Calcutta for the N. W. Frontier in November; but has since been posted as Geologist with the Miranzai Expeditionary Force.

Mr. Oldham succeeded in verifying the reported occurrence of oil at Mogul-kot, in the Sherani country, before the withdrawal of the late Zhob Valley Expeditionary Force. The oil is of fairly good quality, and issues from the springs at about 10 gallons a day. The laboratory examinations of this oil, owing to uncertainty as to the procuring of the samples sent down before Mr. Oldham's visit, are still conflicting: so that a more thorough examination of the springs and their geological conditions will have to be made, when opportunity for further survey occurs.

List of Reports and Papers sent in to Office for publication or record during November and December 1890, and January 1891.

Author.	Subject.	Disposal.
C. L. GRIESBACH . .	Memoir on the Central Himalayas	Will be published immediately as Vol. XXIII, Memoirs of the Geological Survey of India.
R. D. OLDHAM . .	Memorandum on the occurrence of Petroleum.	Will be published in next Records.
C. S. MIDDLEMISS . .	Notes on the Geology of the Salt-Range.	Appears in the current Records.
P. N. BOSE . . .	Extracts from Journal of a Trip to the Glaciers of the Chabru, &c.	Ditto ditto.
DR. NOETLING . . .	Notes on the Structure of the Yenangyoung Oil-fields.	Recorded.
DR. H. WARTH . .	Salts of the Sambhar Lake .	Appears in current Rcords.
"	Analyses of Dolomite from the Salt Range.	Ditto ditto.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1890, and January 1891.

Substance.	For whom.	Result.
Quartz, from Dhadka, for gold.	Geological Survey of India.	Contains no gold.
Quartz, with hornblende-schist and pyrite, for gold.	G. W. IRVING, Calcutta.	
Oligoclase, for determination.	BURN & Co., Calcutta	
Malachite in chlorite-schist, for copper.	G. R. CLARKE, Calcutta.	
Quartz, for gold . .	W. T. CARTER, Calcutta.	
Quartz, for gold . .	C. G. VANSITTART, Calcutta.	
Coal, for assay . .	R. R. WALLER, Calcutta.	
Chalcopyrite in schist, for copper.	JOHN HAY, Calcutta	
Magnetite with quartz, for iron.	Do. do. .	
Quartz, with pyrrhotite, pyrite and chalcopyrite, for gold.	R. R. WALLER, Calcutta.	
Crushed quartz, for gold.	C. G. VANSITTART, Calcutta.	
Quartz, for gold . .	R. R. WALLER, Calcutta.	
Quartz, for gold . .	COL. R. WARBURTON, S.C., Political Officer, Khyber, thro' D. Panioty, Assistant Private Secretary to the Viceroy.	Contains no gold.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1890, and January 1891—continued.

Substance.	For whom.	Result.
Quartz, for gold . .	ULLMANN, HIRSCHHORN & Co., Calcutta.	
Quartz, for gold . .	C. G. VANSITTART, Calcutta.	
Petroleum from 1¼ miles above Mogulkot, Sherani country.	R. D. OLDHAM, Geological Survey of India.	Colour—deep yellow; liquid—begins to thicken at about 54° F.; solidifies at about 32° F. Specific gravity (corrected to 60° F.) ·831. Flashing point (Abel's Test), 128° F. On distillation it yielded:—

	Sp. gr. corrected to 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
Oil distilling between 166° F. & 430° F.	·782	Pale yellowish white	10·00	9·41	Flashing point (Abel's Test) 70° F.
" " 430° F. " 454° F.	·794	" "	10·00	9·56	Flashing point (Abel's Test) 102° F.
" " 454° F. " 480° F.	·803	" "	10·00	9·66	Flashing point (Abel's Test) 127° F.
" " 480° F. " 508° F.	·813	Yellowish white	10·00	9·78	
" " 508° F. " 536° F.	·823	" "	10·00	9·90	
" " 536° F. " 568° F.	·835	" darker	10·00	10·05	
" " 568° F. " 600° F.	·847	Pale yellow	10·00	10·20	
Oil distilling above 600° F.	·857	Yellow	10·00	10·32	
" "	·869	Deep yellow	10·00	10·46	Begins to deposit paraffin at about 50° F., solidifies at about 41° F.
" "	·871	Brownish yellow	8·33	8·73	Begins to deposit paraffin at about 74° F., solidifies at about 58° F.
Paraffin 'scale'	...	......	...	1·73	Solidified in condenser.
Coke	...	......	...	·09	
Loss	...	......	...	·11	
				100·00	

Mica-diorite, with veins of calcite, plagioclase, quartz, hornblende, pyrite, pyrrhotite and chalcopyrite, for gold.	POSNER & Co., Calcutta.	
Galena, with decomposed felspar, for lead and silver.	CAPT. K. M. FOSS, Umballa.	
Pyrite, for gold and arsenic	J. HORSFORD, Calcutta	
Specular iron ore; pig-iron manufactured from the same; and gold nuggets, and the gravel from which they were obtained, for report.	J. M. STONEY, Calcutta.	
Red clay and gravel; and blue quartz, for gold.	J. M. STONEY, Calcutta.	
Impure graphite and graphitic slate, for report.	CAPT. MCLEOD, Jhelum.	
Impure kaolin, for report	BURN & Co., Calcutta.	
Specimens with zinc-blende, pyrrhotite, pyrite, chalcopyrite, calcite, magnetite, quartz and uraninite, for report.	WOMESH CHUNDER BOSE, High Court, Calcutta.	
Kaolin with large quantities of carbonates of lime and magnesia, partially decomposed fragments of felspar and grains of quartz, for report.	COL. MARRIOTT, Lucknow.	

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1890, and January 1891—continued.

Substance.	For whom.	Result.
Sulphate of iron with borax, for report.	WOMESH CHUNDER BOSE, High Court, Calcutta.	
Quartzose gravel, containing garnets and spinels, for opinion.	AUSHOOTOSH DHUR, Attorney-at-Law, Calcutta.	
Quartzite and diorite, for opinion.	J. DEVERIA, Purulia.	
Graphite-powder, for opinion.	F. B. MANSON, Deputy Conservator of Forests, Darjeeling.	
Hematite and quartz; coarse chlorite-schist; and pistacite, for opinion.	JAS. LEONARD, Calcutta.	
Coal, for assay . .	GOPAL CHUNDER MITTER, (Manthdee Coal Concern), Calcutta.	
Red clay and gravel, for gold.	PIERRE CHARRIOL & Co., Calcutta.	
Fire-brick made from Barmoorie clay.	BURN & Co., Calcutta	

Sulphate of iron, with borax and traces of sulphate of magnesia and chloride of soda; tourmaline (schorl); quartz and schorl; magnetic iron ore and quartz; magnetic iron ore; quartzite and several pieces of quartz and felspar, for opinion.	WOMESH CHUNDER BOSE, High Court, Calcutta.	
Quartz, for gold . .	POSNER & CO., Calcutta.	
Ditto . .	CAPT. K. M. FOSS, Umballa.	
Schist with quartz, for gold.	C. G. VANSITTART, Calcutta.	
Ditto ditto .	FATTEH BAHADOOR Giridih.	
Coal (boring sample) .	Bengal-Nagpur Railway Co.	"Boring No. 4, up to 60 feet." Moisture . . . . . 5·60 Volatile matter . . . . 22·44 Fixed carbon . . . . 28·14 Ash . . . . . 43·82 TOTAL . 100·00 Does not cake; ash—light grey.
Wolfram, cassiterite, fragments of quartz, mica and earth, for determination.	T. W. H. HUGHES, Geological Survey of India.	

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1890, and January 1891—concluded.

Substance.	For whom.	Result.			
			No. $\frac{5}{80}$	No. $\frac{5}{81}$	No. $\frac{5}{84}$
Fine quartzose sand with magnetic iron ore and garnets, for opinion.	Jas. Luke, Calcutta.				
Rock crystal, for opinion.	Lauchlan J. Mackintosh, Calcutta.				
Chlorite schist, for opinion	Jas. Leonard, Calcutta.				
3 specimens of dolomitic sandstone, from the Salt Range, collected by A. B. Wynne.	Geological Survey of India.	Silica and other insolubles	5·0	6·0	61·6
		Alumina and oxide of iron, &c. . . .	1·9	1·7	1·4
		Calcium carbonate	51·6	51·0	20·6
		Magnesium carbonate (by difference) . .	41·5	41·3	16·4
			100·00	100·0	100·0
Galena, for lead and silver	L. G. Prickett, Under Secretary to Govt., D. P. W., Railway Branch.				
Mica-diorite, with veins of calcite, quartz, plagioclase, chalcopyrite, pyrite, &c., for gold.	Posner & Co., Calcutta.				
5 samples of quartz, for gold.	C. G. Vansittart, Calcutta.				

4 samples of coal from Darjeeling, for determination.	P. N. Bose, Geological Survey of India.		"III.—Rungtong Jhora. By D. H. Railway. Lower outcrop."	"IV.—Above junction of Kali Jhora with the Tista. By the cart road."	"V.—Kali Jhora, Tista valley."	"VII.—Kali Jhora, Tista valley."
		Moisture	5·74	3·00	2·52	4·92
		Volatile matter	16·80	12·16	11·76	13·90
		Fixed carbon	41·82	72·60	39·72	54·98
		Ash	35·64	12·24	46·00	26·20
			100·00	100·00	100·00	100·00
			Cakes, but not strongly. Ash—light grey.	Does not cake, but sinters slightly. Ash—light red.	Cakes, but not strongly. Ash—light red.	Cakes, but not strongly. Ash—light grey.
5 specimens supposed to be antimony.	Dy. Commissioner, Lalitpur.	Fine-grained dolerites (anamesite).				
Stibnite, for opinion	Arracan Co., Ld., Calcutta.					
Quartz and felspar, for opinion.	G. T. Peppe, Ranchi.					

Notifications by the Government of India during the months of November and December 1890, and January 1891, published in the "Gazette of India," Part I.—Appointment, Confirmation, Promotion, Reversion and Retirement.

Department.	Number of order and date.	Name of officer.	From	To	Nature of appointment, &c.	With effect from	Remarks.
Revenue and Agricultural Department.	$\frac{1370}{16\text{-}30}$S., dated 19th November 1890.	T. H. Holland	...	3rd grade Assistant Superintendent and Curator.	Substantive.	21st October 1890.	
Ditto .	$\frac{1539}{93\text{-}29}$S., dated 11th December 1890.	R. D. Oldham	Officiating Superintendent.	Deputy Superintendent, 1st grade.	Do. .	3rd November 1890.	

Notifications by the Government of India during the months of November and December 1890, and January 1891, published in the "Gazette of India," Part I.—Leave.

Department.	Number of order and date.	Name of officer.	Nature of leave.	With effect from.	Date of return.	Remarks.
Revenue and Agricultural Department.	...	P. Lake .	Privilege leave .	8th October 1890.	...	Not returned.
Ditto .	$\frac{1539}{93\text{-}29}$S., dated 11th December 1890.	Theo. W. H. Hughes.	Special leave for 6 months.	23rd May 1890.	3rd November 1890.	

Annual Increments to Graded Officers sanctioned by the Government of India during November and December 1890, and January 1891.

Name of officer.	From	To	With effect from	Number and date of sanction.	Remarks.
	R	R			
T. D. La Touche	580	620	1st October 1890.	Revenue and Agricultural Department No. $\frac{1332}{109-11}$ S., dated 1st November 1890.	
C. S. Middlemiss	540	580	1st November 1890.	Revenue and Agricultural Department No. $\frac{1403}{109-15}$ S., dated 21st November 1890.	

Postal and Telegraphic Addresses of Officers.

Name of officer.	Postal address.	Nearest Telegraph Office.
R. Bruce Foote	Kadiri	Cuddapah.
T. W. H. Hughes	Mergui	Tavoy.
C. L. Griesbach	Miranzai Field Force, *viâ* Kohat.	Kohat.
R. D. Oldham	Sibi, (Baluchistan)	Sibi.
P. N. Bose	Gantok, (Sikkim)	Darjiling.
T. H. D. LaTouche	Palamow, Bengal	Barun.
C. S. Middlemiss	Rawalpindi	Rawalpindi.
P. Lake	Not returned from leave.	
P. N. Datta	Tura, (Assam)	Dhubri.
F. Noetling	Yenangyoung, (Upper Burma).	Yenangyoung.
Hira Lal	Sibi, (Baluchistan)	Sibi.
Kishen Singh	Babarkuch, Ditto	Babarkuch.

ERRATA.

RECORDS OF THE GEOLOGICAL SURVEY OF INDIA, VOL. XXIV, PART 1.

Page 46, 1st line from top, for Kabru, *read* Kabur.

" 57, 28th " " " " " " "

ERRATA.

Memoirs, Geological Survey of India, Vol. XXIV, Pt. 1.

Page 1, in second line of title, *for* A *read* J.
,, 3, line 13, *for* on *read* of.
,, 4, line 6, *below* Talchir *insert* Metamorphics.
,, 5, last line (references), *for* 4 *read* 5, and *for* 5 *read* 4.
,, 7, line 1, *for* 1854 *read* 1855.
,, 7, line 5 from bottom, *for* Q. J. Geol. Soc., London, XI, 555, *read* J.A.S.B. XXIV, 347-353.
,, 7, line 3 from bottom, *for* V, 179 *read* XI, 555.
,, 8, in marginal heading of last paragraph, *for* 1886 *read* 1866.
,, 9, line 16 from bottom *erase* 7 after 1872.
,, 15, line 9, *for* Optee *read* Ooptee.
,, 15, line 10, *for* Omerghor *read* Oomerghor.
,, 32, in well section, *insert* White sandstone—15′ 0″ *above* Coal—1′ 0″.
,, 35, line 2 from bottom, *for* Gogra *read* Gogri.
,, 37, line 4 from bottom, *for* Badeo *read* Badee.
,, 39, line 8 from bottom, *for* following *read* flowing.
,, 49, line 1, *for* Sungun *read* Sungum.
,, 52, line 11, *for* Lenia *read* Lonia.
,, 54, line 2 from bottom, *for* Tannia *read* Tamia.
,, 54, bottom line, *for* Sarni-Patakkra *read* Sarni-Patakhera.
,, 56, No. XIV in table, *for* Gajimdoh *read* Gajundoh.
,, 56, No. XVI, in table, *for* Pala Chourye *read* Pala Chowrye.
,, 58, line 2 from bottom, *for* deposited *read* dissolved.

In map I (1″=4 miles), in scale of horizontal section, *for* 1056′ *read* 10560′.
In upper margin, *for* Singora field *read* Sirgora field.
The small outlier north of Rajegao coloured as Trap should be coloured as Motur s.
In map II, in upper margin, *for* "Singora" *read* "Sirgora."

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1891. [May.

Preliminary Report *on the* Oil locality *near* Moghal Kot, *in the* Sheráni country, Suleiman Hills, *by* R. D. OLDHAM, F.G.S., *Deputy Superintendent*, *Geological Survey of India.*

Position of the springs.

The petroleum which I was instructed to examine and report upon issues in several spots from a band of hard, unfossiliferous sandstone, probably of a cretaceous age and about 600 feet in thickness. The most abundant springs are close to the base of this band of sandstone, where three thin bands of soft porous rock form conduits along which the oil works upwards from below. The actual points of issue are in the river-bed, and are determined by the profile of the out-crop of the oil-bearing strata. Traces of old flows and rock, blackened and impregnated with dried-up oil, are found for a height of 60 feet above the water, showing that the flow of oil has been continuous for at least the period required to deepen the gorge by 60 feet. Probably the flow has been going on for a much longer period, but at a greater height above the stream the outcrops of the porous beds are hidden by recent gravels.

Nature of the oil.

The oil is clear, limpid, of a pale yellow colour, and, as it issues from the rock, perfectly free from water. There is no reason for doubting that the samples examined in Calcutta by the Chemical Examiner to the Bengal Government, and in the Laboratory of the Geological Survey of India, were genuine samples of the oil as it issues from the rock; and the result of those examinations is sufficient to show the high value of the oil if it is procurable in any quantity. The actual outflow of oil at the springs is probably small, not more than 10 gallons a day at the time when I visited them. This could doubtless be increased to some extent by pits or borings, but, owing to the high angle of dip of the rocks and the consequent easy escape naturally afforded, I do not anticipate that the increased yield so obtained would repay the expense incurred.

Strcuture at Moghal Kot.

No other springs of petroleum appear to be known in this district. It is probable that a detailed examination would show traces of oil in other localities also, but there is a special structural reason why there should be an easily recognizable oil spring at this spot. The gorge of the stream happens to cut across the crest of a very open anticlinal fold whose axis dips to E N. E. at 30°, so that the oil working up from below would become concentrated along the very line where the lowest point in the outcrop of the porous beds occurs. I do not consequently attach great importance to the absence of other known occurrences of oil springs.

Anticlinal Parwara.

From Moghal Kot down to Parwara the rocks maintain a steady dip to about E. N. E., the local dips varying from N. N. E. to E. Below Parwara the dip is reversed, and between it and the plains there is a well-defined anticlinal, whose crest lies at Dwamandi. Under this anticlinal there is probably a considerable accumulation of oil; but, so far as my observations along the line of march go, there is no bed well adapted to serve as a reservoir which would be reached at a reasonable depth.

General conclusions.

The general conclusions to be drawn from what I have seen are, that there can be no doubt of the existence of oil of excellent quality and great value in the district, but that it would be premature to undertake any expensive operations at present. It is, however, important that, as soon as the country is sufficiently settled to allow of it, a thorough and systematic exploration should be undertaken, with a view to determining whether there are any localities where it is probable that oil occurs in sufficient quantity, and at a depth which would render its profitable extraction possible.

On Mineral Oil *from the* Suleiman Hills, *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Geological Survey of India.*

A careful examination has been made in the laboratory of the specimen of oil collected by Mr. R. D. Oldham, F.G.S., at a point "one and a half miles above Moghal Kot, Choha Khel Dana, Suleiman Hills," with the following results:—

Physical properties.

The sample received was a deep yellow liquid with slight fluorescence, flocculent sediment, and a globule of water at the bottom of the bottle (*vide* page 90).

The odour of the liquid was less aromatic than that of the ordinary commercial American kerosine oil obtained in the Calcutta market.

It was mobile at the temperature of the laboratory (75° Fahr.), but began to thicken on cooling to 54° Fahr., on account of the crystallization of the heavier hydrocarbons, and completely solidified at about 32° Fahr. The specific gravity at 60° Fahr. was 0·831.

The "flashing" point, determined by means of the apparatus devised by Sir Frederick Abel and adopted as the legal standard by the Government, was found to be 128° Fahr.

Fractional distillation.

A measured quantity of the oil was subjected to fractional distillation with the following results:—

Temperature of Distillation.	Distillate.			
	Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.
1st fraction distilling between 166° F. and 430° F. .	·782	Pale yellowish white	10	9·41
2nd „ „ „ 430° F. „ 454 F. .	·794	Ditto .	10	9·56
3rd „ „ „ 454° F „ 480° F.	·803	Ditto .	10	9·66
4th „ „ „ 480° F. „ 508° F. .	·813	Yellowish white .	10	9·78
5th „ „ „ 508° F. „ 536° F. .	·823	Ditto .	10	9·90
6th „ „ „ 536° F. „ 568° F. .	·835	Ditto .	10	10·05
7th „ „ „ 568° F. „ 600° F. .	·847	Pale yellow . .	10	10·20
8th „ „ above 600° F. . . .	·857	Yellow . . .	10	10·32
9th „ „ „ „ . . .	·869	Deep yellow . .	10	10·46
10th „ „ „ „ . . .	·871	Brownish yellow .	8·33	8·73
Paraffin 'scale'	..	......	...	1·73
Coke	...	......	...	·09
Loss	...	......	...	·11
				100·00

The 1st fraction distilling between 166° F. and 430° F. was found, on the application of Abel's test, to have a flashing point at 70° F.; the 2nd fraction, distilling between 430° F. and 454° F., flashed at 102° F.; whilst the 3rd distillate showed no signs of inflammable vapour until the temperature of 127° F. was reached. Hydrocarbons, solid at ordinary atmospheric temperatures, distilled over plentifully with the 9th fraction, which began to deposit paraffin on cooling to 50° F. and solidified at 41° F. Of the remaining tenth 8·33 per cent. of the *original* volume distilled over, and deposited solid paraffin on cooling to 74° F., completely solidifying at 58° F. A quantity of matter solidified in the condenser (1·73 per cent. by weight), forming what is technically termed the paraffin 'scale.' The carbonaceous residue amounted to 0·09 per cent. The total of these indicates a most unusually small proportion (0·11 per cent.) of loss, which I believe to be due to a simple modification made in the usual form of apparatus (*vide* page 87). From the series of specific gravity determinations of the successive fractions of the distillate, it will be seen that there is a gradual increase in the density, coincident with a deepening colour, and, so far as Sir Frederick Abel's apparatus will allow of a determination, of a gradually rising flashing point. There is, therefore, no evidence of the oil having "cracked" during the operation.

The quantity of oil supplied being very limited, I am unable to make any further experiments for the purpose of ascertaining the exact percentage of oil available for illuminating purposes. It is possible, however, to form a fairly accurate opinion from the facts obtained during the fractional distillation. The limit at most must be placed at 30 per cent., the heavier oils above this being unfitted for burning in the forms of apparatus at present in general use for that purpose, whilst the three fractions distilling below 480° F. would, if mixed, give a sample with a density agreeing with the American commercial oils, but with a flashing point undesirably high. In the processes adopted in metal-retorts on a manufacturing scale, experiment might result in a higher yield of illuminating oil by cracking the heavier forms of liquid hydrocarbons. This seems the more probable from the large proportion of these liquid compounds, and the small quantities of solid hydrocarbons, the first eight fractions being free from these latter bodies.

Illuminating oil.

Comparison with other Sheráni oils.

Compared with other samples obtained from this district, the specimen sent by Mr. Oldham must be considered to be decidedly inferior in quality.

In December, 1889, samples stated to be raw mineral oil were forwarded from Dera-Ismail-Khan by P. Broadway, Esq., District Superintendent of Police. These were separately examined by Dr. Warden, Chemical Examiner to the Bengal Government, and in the laboratory of the Geological Survey by Mr. P. Lake.

Dr. Warden found the specimen to have a specific gravity of 0·8209 at 15·5° C., and a flashing point of 89° F.; and in his report concludes from his examination that the specimen was "*not a crude*, but a commercial kerosine oil of Russian origin." Mr. Lake found the sample submitted to him to have a density of 0·822 and a flashing point of 89° F.

In September, 1890, Dr. Warden reported on a further specimen of mineral oil from the Sheráni country, procured by the Deputy Commissioner of Dera-Ismail-Khan on the slopes of the Takht-i-Suleiman. He found it to have a specific gravity of 0·8154 (at 15·5° C.) and a flashing point of 84·29° F. Its density and flashing point indicate, therefore, a state of purity far superior to the sample received from Mr. Oldham. A comparison of the results of fractional distillation confirms this conclusion—

	Specific gravity at 60° F. A.	Specific gravity at 60° F. B.
1st fraction of 10 per cent.	·7557	·782
2nd " "	·7685	·794
3rd " "	·7802	·803
4th " "	·7948	·813
5th " "	·8077	·823
6th " "	·8204	·835
7th " "	·8367	·847
8th " "	·8487	·857
9th " "	·8596	·869

A. Mineral oil procured by the Deputy Commissioner of Dera-Ismail-Khan and examined by Dr. Warden.

B. Mineral oil procured by Mr. Oldham and examined in the laboratory of the Geological Survey of India.

It might be noticed that there is a close agreement, especially in the earlier portions, between the specific gravities of the several fractions obtained during the fractional distillation of Mr. Oldham's sample and the results obtained by Mr. Boverton Redwood (Jour. Soc. Chem. Ind., Vol. IV, p. 76) from several samples of Russian kerosine. I append these results in parallel columns for comparison—

Comparison with Russian kerosines.

	Crude oil from Moghal Kot (sp. gr. 0·831).	Russian kerosine (sp. gr. 0·822).
1st fraction of 10 per cent.	·782	·783
2nd " "	·794	·796
3rd " "	·803	·803
4th " "	·813	·814
5th " "	·823	·827
6th " "	·835	·831
7th " "	·847	·837
8th " "	·857	·838
9th " "	·869	·846

This agreement in the densities of the distillates might at first seem discordant with the flashing points; but it appears from the researches of Beilstein, Schützenberger and others that the higher specific gravity of Russian kerosines, when compared with American and other commercial oils, is due to the large quantities of isomers of the olefine series (naphthenes) in the Caucasian products, whilst the various members of the isologous series of paraffins which predominate in the American petroleum have, for corresponding boiling points, lower specific gravities. The conversion of the latter into the former has been shown by Thorpe and Young to be the result of the process termed "cracking," and this fact must be taken into consideration in comparing the results of the fractional distillation of crude oils and those of commercial oils, which, like most American samples, have been "cracked." The agreement, therefore, of the specific gravities of the oil from the Sheráni country and that of marketable Russian kerosines does not necessarily indicate a corresponding commercial value.

In the fractional distillation of mineral oils the loss commonly amounts to between 3 and 5 *per cent.*, which seems due to the escape of hydrocarbons between the neck of the retort and the condenser. Unless the flashing point of the oil is very low and the temperature of the laboratory high, there can be no appreciable escape at the lower end of the condenser,—practically none after the first fraction.

Modification of the still.

In order to prevent the escape at the junction of the neck of the retort and the condenser, I have used a thick india-rubber tube which fits *around* the neck of the retort and tightly *into* the condenser. This allows of a considerable latitude of oscillatory movement and at the same time preserves a vapour-tight joint.

The only objections which I can see to this simple contrivance are, (1) the action of the hydrocarbons on the caoutchouc and (2) the effect of the high temperature on the rubber.

In consideration of each of these I have made a series of experiments which seem to show that these objections are of little practical concern.

Action of kerosine on india-rubber.

(1). To test the action of the oil on the caoutchouc, a piece of the red rubber, weighing 7·7282 grammes, was used. Its specific gravity, both by weighing in water and by floating in a solution of salt, was found, as the average of closely agreeing results, to be 1·05. It was then immersed for twenty-four hours in the first distillate obtained from petroleum distilling below 430°F., and having a specific gravity of ·7803 at 60° F. (·7727° at 79° F.). On cleaning with weak alcohol the rubber was found to have increased in weight by the absorption of the liquid hydrocarbons to 21·370 grammes, indicating an absorption of nearly double its own weight. It had increased considerably in bulk, the specific gravity being reduced to ·840, so that it easily floated on water. The residue of the liquid showed no change in its density (·774 at 76° F.). There was nothing, therefore, dissolved from the rubber which might affect the characters of the oil.

After three months' exposure to the open air at a temperature ranging between 75° and 85° F. the rubber became reduced to 13·563 grammes and would still float in water. On raising the temperature to 200° F. for four hours its weight quickly descended, although the vessel in which it was contained was kept filled with the vapours given off, and the specific gravity was so reduced that it again sank in water.

I do not see that the distillates from the petroleum could in any way be affected by solution of the rubber; and at a high temperature, exposed only to vapours, the absorption must, on account of the small surface presented and that under pressure be inappreciable.

Effect of high temperature.

Pure caoutchouc begins to melt at 248° F. Its melting point is considerably raised by vulcanization and the introduction of mineral colouring matter, by which means the caoutchouc is reduced sometimes to 50 *per cent.* of the rubber.

By enveloping the joint with cotton-wool and packing in a thermometer, I found the temperature throughout the distillation never exceeded 270° F., and by removing the joint further from the retort the temperature can be kept still lower. There is thus no fear of the results being affected by the melting of the caoutchouc. The rubber may be found to have just adhered slightly to the glass, but shows no other signs of change. I have, consequently, considered it unnecessary to ascertain if any isoprene or caoutchene had been given off. These substances, moreover, would have all been lost during the vulcanization of the caoutchouc; and, if there was a possibility of the rubber giving off any vapours at such a low temperature, they would have found their way into the open air rather than into the condenser. Certainly, such would have no appreciable effect upon the distillates. The simplicity of the arrangement is the only apparent reason left for supposing its adoption must be accompanied by some source of error.

Hydrocarbons in the crude oil.

With the small quantity of material at my disposal, it was impossible to attempt a complete proximate analysis of the Sheráni oil. From the researches of a large number of workers, most petroleums appear to be composed principally of a complex mixture of homologues and isomers of the paraffin series ($C_n H_{2n+2}$), and Warren[1] was able, in 1868, by means of an improvement in the method of fractional distillation[2], to add to the results obtained by Pelouze and Cahours[3] by showing the existence also in the Pennsylvanian oil of homologues of the series C_nH_{2n}. Following these, which have been found in varying proportions in all crude petroleums, comes the interesting question of the presence of members of the benzene series (C_nH_{2n-6}).

In 1856, Warren de la Rue and Hugo Müller announced the discovery in Rangoon tar of the hydrocarbons benzene (C_6H_6), toluene (C_7H_8), xylene (C_8H_{10}) and cumene (C_9H_{12}).[4]

In 1860, Bussenius and Eisenstuck found xylene in a sample of Hanoverian petroleum.[5]

In the same year, Pebal and Freund obtained five homologues of this series in naphtha from Galicia.[6]

In 1863, J. Pelouze and A. Cahours, whilst recording the occurrence in Pennsylvanian petroleum of homologues of the marsh gas series from $C_4 H_{10}$ to $C_{15} H_{32}$, besides possibly higher solid paraffins,[7] distinctly denied the presence of the benzols.[8]

In 1865, Schorlemmer, in the first of an exhaustive series of researches on the hydrocarbons of the series $C_n H_{2n+2}$, showed the existence in Canadian rock-oil of the benzols.[9]

In 1867, the results of de la Rue and Müller were confirmed by the detection in Rangoon tar of xylene and isocumene by Warren and Storer.[10]

In 1876, Beilstein and Kurbatow obtained additive products of benzene (hexhydrobenzene, $C_6 H_{12}$, &c.) in Caucasian petroleum;[11] whilst in 1878, and again in 1882, Markownikoff and Oglobini obtained isomerides of this series in oil from the same locality.[12] These results were confirmed by Markownikoff in 1886, when he pointed out the existence of the naphthenes already referred to[13] (*ante, p.* 87). Many of the other results have also been confirmed by different authors, notably the occurrence of the aromatic hydrocarbons in Galician petroleum by Lachowicz and by Pawlewski.

Presence of the series $C_n H_{2n-6}$ in the Baluchistan oil.

In examining the Sherani oil for aromatic hydrocarbons,

[1] "Hydrocarbons of Pennsylvanian petroleum."—*Amer. Journ. Sci.*, ser. 2, vol. xlv, (1868), p. 262.

[2] "On a process of fractional condensation applicable to the separation of bodies having small differences in their boiling points."—*Amer. Journ. Sci.*, ser. 2, vol. xxxix (1865), p. 327.

[3] "Recherches sur les pétroles d'Amérique."—*Comptes Rendus*, vol. lvi (1863), p. 505, and vol. lvii (1863), p. 62.

[4] *Proc. Royal Soc.*, vol. viii (1856), p. 225.

[5] *Ann. Chem. u. Pharm.*, vol. cxiii (1860), p. 151.

[6] *Ibid.*, vol. cxv (1860), p. 19.

[7] *Comptes Rendus*, vol. lvii (1863), p. 62.

[8] *Loc. cit.*, p. 69.

[9] *Proc. Royal Soc.*, vol. xiv (1865), p. 168 (foot-note).

[10] *Amer. Journ. Sci.*, ser. 2, vol. xliii (1867), p. 251. (Abstract of paper from *Mem. Amer. Acad.*, new ser., vol. ix, p. 208.

[11] *Ber. Deutsch. Chem. Ges.*, vol. xiii, p. 1818 and vol. xiv, p. 1620.

[12] *Journ. Chem. Soc.*, vol. xlii, p. 390, and vol. xlvi, p. 1276.

[13] *Journ. Chem. Soc.*, vol. l (1886), p. 1015 (Abstract).

I have followed the method used and described by Schorlemmer in the classic researches already quoted.[1]

A portion was distilled below 300° F., and the distillate treated with fuming nitric acid to produce the nitro-substitution products (Mitscherlich's 'nitrobenzides'[2]) which were separated after dilution with water. When exposed to the action of nascent hydrogen the nitro-benzene (taking the initial term in the series) was reduced to the corresponding amidobenzene ($C_6H_5NH_2$, or aniline), and the solution then distilled with caustic potash. The aqueous distillate gave the characteristic violet colour when treated with an alkaline hypochlorite. In this manner I treated three portions of the oil, but one of the re-actions failed on account of the acid being mistaken. In the other two the characteristic re-actions of the benzene series were most decided.

Salts dissolved in the water accompanying the crude oil.

I have made a careful qualitative examination of the small quantity of water which separated at the bottom of the sample of oil. The water gave distinctly acid re-actions with litmus, and I found that both sulphates and sulphides existed in combination with lime and traces of iron and magnesia. The lime was obtained as a sulphate in minute, characteristic, monoclinic combinations and twins of gypsum, on slow evaporation of the water under the microscope.[3]

A portion of the water was treated with a drop of nitric acid, ammonic chloride and ammonia, filtered, concentrated, and a drop of the filtrate placed on a slide. A drop of sodic phosphate solution and ammonia was placed near the first drop, and the two, after raising the temperature, were connected with a fine capillary tube of glass, when the formation of rhombic combinations of ammonic magnesic phosphate was observed under the microscope.[4]

I was unable to obtain definite re-actions for chlorides, nitrates or sulphides

In describing the Khatan oil-fields, Mr. R. A. Townsend, in a previous volume of the Records, mentions the occurrence of sulphuretted hydrogen, sulphurous acid, sulphur, gypsum and pyrites in connection with the oil springs.[5]

Previous examinations of Baluchistan oil.

Amongst the analyses made in the laboratory of the Geological Survey, I find two accounts of Baluchistan oil which have not as yet been published.

In 1886, the late Mr. E. J. Jones determined the specific gravity of a sample of "crude petroleum from Khatan, Beluchistan." He says that it "floats on water, while with the hydrometer it gives a specific gravity of 1·005, the same hydrometer giving a specific gravity of 0·995 with water at a temperature of 86° F."

In June, 1887, Mr. F. R. Mallet gives the following results of his examination of crude petroleum from Khatan, Beluchistan:—

"Dark brown colour; thick and ropy consistency; specific gravity, 1·008 at 88° (or 1·019 at 60° F.)

[1] *Loc. cit.*, p. 168.

[2] *Pogg. Ann.*, vol. xxxi, p. 625.

[3] Behrens' test, "Mikrochemische Methoden zur Mineralanalyse."—*Verslagen en Mededeelingen d. k. Akad. van Wetensch.* Amsterdam, 1881, p. 47.

[4] Behrens, *loc. cit.*, p. 55.

[5] *Rec. Geol. Surv. Ind.*, vol. xix (1886), pp. 208 and 210.

"On distillation it yielded:—

	Sp. Gr. at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	Remarks.
Water . . .	...	......	3	2·96	Neutral to litmus.
Oil distilling between 260° F. and above 600° F.	·888	Pale yellow . .	10	8·70	Did not flash at 148° F. (Abel's test). Only about 3 per cent. of oil distilled below 600° F.
Oil distilling above 600° F.	·919	Yellow . . .	10	9·00	
Ditto . .	·933	Darker yellow .	10	9·14	
Ditto . .	·934	Deep yellow . .	10	9·15	
Ditto . .	·931	Yellowish red . .	10	9·13	"Cracked."
Ditto . .	·931	Red . . .	10	9·13	"Cracked."
Ditto . .	·934	Red . . .	10	9·15	
Ditto . .	·958	Deep red . .	10	9·40	Deposited a little paraffin at 50° F.
Ditto . .	1·065	Very deep red .	2·3	2·43	Do. Became thick when cooled to 86° F.
Paraffin 'scale' .	...	......	...	1·07	Solidified in condenser.
Coke . . .	...	......	...	16·24	
Loss . . .	...	......	...	4·50	
				100·00	

"Owing to the water contained in the crude petroleum, the latter foams up and pours into the condenser unless the heat is properly managed. When heated very gently for a sufficient length of time, the water distills over first, after which the temperature may be raised and the oil distilled without risk of foaming.

"The following results were obtained on partial distillation of the oil:—

No. 1.

	By volume.	By weight.
Water	2·8	2·8
Oil of sp. gr. ·928 at 60° F.	71·4	65·8
Pitch	...	30·2
TOTAL .	...	98·8

Pitch brittle and easily powdered at 85° F.

No. 2.

	By volume.	By weight.
Water	2·8	2·8
Oil of sp. gr. ·915, at 60° F.	61·0	55·4
Pitch	...	38·8
TOTAL .	...	97·0

Pitch brittle and pulverizable at 85° F., although not quite so easily as No. 1.

No. 3.

Water	3·0	3·0
Oil of sp. gr. ·916 at 60° F.	57·6	52·4
Pitch	...	43·0
TOTAL	...	98·4

Pitch not pulverizable at 85° F., but brittle and pulverizable at 55° F.

No. 4.

Water	2·8	2·8
Oil of sp. gr. ·915 at 60° F.	51·7	46·6
Pitch	...	51·4
TOTAL	...	100·8

Experiments on the manufacture of patent fuel, from Chitteedand (Salt-range) Coal No. $\frac{7}{212}$, Khatan Petroleum, and pitch made from the petroleum (in experiment No. 1)—

A.	Pitch	10	Heated to about 620° F (temperature of melting lead.)	Friable.
	Coal	90		
	TOTAL	100		
B.	Pitch	15	Ditto	Considerably firmer than A.
	Coal	85		
	TOTAL	100		
C.	Pitch	20	Ditto	Possessed of a considerable degree of firmness, more so than B.
	Coal	80		
	TOTAL	100		
D.	Crude petroleum	17·73	Unbaked	Very little firmness.
	Coal	82·27		
	TOTAL	100·00		
E.	Crude petroleum	17·73	Ignited in a close vessel to a low red heat.	Weak.
	Coal	82·27		
	TOTAL	100·00		
F.	Pitch	6·45	Ditto	Fairly strong.
	Crude petroleum	5·85		
	Coal	87·70		
	TOTAL	100·00		
G.	Pitch	9·18	Ditto	Not very different from E.
	Crude petroleum	8·26		
	Coal	82·56		
	TOTAL	100·00		
H.	Pitch	15	Ditto	Strong. Promising.
	Crude petroleum	5		
	Coal	80		
	TOTAL	100		

On the origin of the benzenes.

At the conclusion of his paper on the Khatan oil-field, Mr. Townsend says (*loc. cit.*, p. 210): "It has occurred to me as a tenable theory that the petroleum of this locality may be produced by the action of sulphurous acid waters, combined with alkalies, all at a moderately high degree of heat acting chemically upon a deep deposit of coal, or lignite, under confinement, and it may be that all petroleum has a similar origin."

The author has failed to point out the precise chemical changes whereby "sulphurous acid waters combined with alkalies" convert coal or lignite into petroleum. As he has given no clue to the nature of the organic compounds in the Khatan oil, it is difficult to see the steps by which he has been led to such a generalization.

In studying the evidence which bears on the subject of the origin of petroleum most writers have been in the habit of dealing with generalities too vague to be corrected by subsequently discovered facts. The large number of hydrocarbons of which nearly all mineral oils are composed are often lumped together as possible products of destructive distillation of organized matter, and as mutually convertible; whereas the organic compound, as well as the inorganic body, possesses a distinct individuality and only a possible set of conditions for existence. If ever the solution of the complicated problem of the origin of petroleum be accomplished it can only be by a careful and accurate detailed study of the characters of the individual organic bodies of which it is composed, together with the geological conditions of its occurrence.

I propose here only to point out some of the points in the chemical characters of the benzols which seem to have an important bearing on the subject, many of which have not, so far as I am aware, been hitherto considered in discussing the origin of petroleum, and which may be of service to field-workers who are making a special study of the geological conditions under which the Baluchistan oil occurs.

I have already quoted a sufficient number of authors to show that, notwithstanding the remarks of Pelouze and Cahours, the presence of the benzene series in crude petroleums seems to be true for an increasing number of localities.

Some of the many explanations for the formation of mineral oil which have been proposed have been concisely reviewed in a previous volume of the Records by the late Director, Mr. H. B. Medlicott.[1]

Since Faraday's discovery in 1825 of benzene,[2] a large number of its homologues, and members of the parallel series and derivatives, have been found in the products of the destructive distillation of organic bodies; and this fact has been in a general way used in support of the theory for the organic origin of petroleum. But a long series of researches have revealed the presence of many aromatic compounds occurring also as natural constituents of both animal and vegetable matter.

Catechol (orthodihydroxylbenzene), whose properties have been investigated successively by Reinsch, Zwenger and Wagner, occurs in the extracts of nearly all plants which contain tannic acid. It is found in the juice of *Pterocarpus*, *Eucalyptus* and *Butea*, in the bilberry plant, and in the autumnal leaves of the Virginia creeper.[3] Resorcinol (or metadihydroxylbenzene, $C_6H_4(HO)_2$) occurs in many

[1] *Rec. G. S. I.*, vol. xix (1886), p. 187.
[2] *Phil. Trans.*, 1825, p. 440.
[3] Flückiger: *Ber. Deutsch. Chem. Ges.*, vol. v, p. 1.

resins and in *Asafœtida*, *Acaroïd* and *Sagapenum*,[1] Quercitol ($C_6H_7(HO)_5$) was found by Bracconot in the acorn, and again by Dessaignes in the leaves of the Fan palm (*Chamærops humilis*).[2]

But of the members of the aromatic group probably the natural occurrence of phenol is the most interesting in the present instance. The existence of phenol (C_6H_5HO, or carbolic acid) has long been known as a product of the destructive distillation of wood and other organic bodies. So long ago as 1834 it was found by Runge in coal-tar.[3] The researches of Städler,[4] Baumann,[5] Salkowski,[6] and Munk[7] have established its presence in various excretory products of mammals. Wöhler has shown its existence in castoreum, a substance secreted by the præputial glands of the beaver.[8] Its occurrence also in some plants has been recorded.[9]

The occurrence of phenol in both animals and plants has a most significant bearing upon the question of the organic origin of the aromatic hydrocarbons in petroleum, for, by the simplest change, this compound is reduced to the hydrocarbon benzene (C_6H_6). In fact, it was Baeyer's experiments[10] on the reduction of the oxidized aromatic compounds to their corresponding hydrocarbons that led to the discovery of artificial alizarin, the colouring matter of madder.

At high temperatures phenol is, according to Krämer's experiments, broken up into benzene (C_6H_6), toluene (C_7H_8), xylene (C_8H_{10}), naphthalene ($C_{10}H_8$), and phenanthrene ($C_{14}H_{10}$).[11]

It is thus seen that phenol, which occurs as a constituent of some organic bodies, is converted by heat alone, or with reducing agents, into hydrocarbons which are being found now in most mineral oils, and this fact points to the organic origin of petroleum, a conclusion which seems in no way discordant with the geological conditions under which the crude oil occurs. Of the presence of de-oxidizing agents in the Baluchistan area sufficient evidence is obtained from Mr. Townsend's account of the presence of pyrites, sulphur and "sulphurous acid waters."[12] I have also found sulphites in the water accompanying the oil collected by Mr. Oldham.

The heat evolved during the crumpling and contortion of the rocks accounts for that factor in the decomposition of the phenol. Moreover, Mr. Townsend quotes

[1] *Ann. Chem. u. Pharm.*, vol. cxxx p. 354; *Ibid.*, vol. cxxxviii, p 63, and vol. cxxxix, p. 78.

[2] *Comptes Rendus*, vol. xxxiii, pp. 308 and 462.

[3] *Pogg. Ann.*, vol. xxxi, p. 65, and xxxii, p. 308.

[4] *Ann. Chem. u. Pharm.*, vol. lxxvii, p. 18.

[5] *Ber. Deutsch. Chem. Ges.*, vol. ix, p. 55.

[6] *Ibid.*, vol. ix, p. 1595.

[7] *Ibid.*, vol. ix, p. 1596.

[8] *Ann. Chem. u. Pharm.*, vol. lxvii, p. 360.

[9] Mr. A. H. Allen, in his Commercial Organic Analysis, 2nd edition (1886), vol. ii, p. 536, says, "Phenol is alleged to exist in the leaves, stem and cones of *Pinus sylvestris*." Since writing the above I have found an article by Dr. A. B. Griffiths describing his discovery of "the occurrence of phenol in the stem, leaves and cones of *Pinus sylvestris*" (*Chem. News*, vol. xlix (1884), p. 95). The author has also suggested this as the source of the phenol found in mineral oil by Freund and Pebal.

[10] *Ann. Chem. u. Pharm.*, vol. cxl, p. 295.

[11] *Ibid.*, vol. clxxxix, p. 129.

[12] *Loc. cit.*, pp. 208, 209 and 210. I presume by "sulphurous," the author means water in which shulphur*ous* anhydride (SO_2) is dissolved, not sulph*ates* or sulphur*ic* anhydride (SO_3).

more direct evidence in the actual high temperature of one of the springs in the Khatan field, which has a temperature of 109° F., at *the point of overflow*.[1]

The occurrence of phenol itself in mineral oil from Galicia has been recorded by Pebal and Freund in the memoir to which reference has already been made[2] from the Caucasus by Markownikoff and Oglobini,[3] and from Hanoverian oil by Krämer and Böttcher.[4]

In tracing here the simple series of changes chemically and geologically feasible for the production of the aromatic hydrocarbons and alcohols from organic sources, I am not suggesting that this is the only manner in which these compounds are produced in petroleum. Much confusion has arisen, not only from considering the organic compounds as one group with common properties, but also by supposing that any particular hypothesis is capable of general and exclusive application. Hydrocarbons of this series have been artificially prepared by processes purely inorganic by a large number of researchers, notably Berthelot (in 1866 and subsequently), Byasson (in 1871), Friedel and Crafts (in 1877), Mendeljeff (in 1877), Clœz (in 1877) and by Landolph (in 1878); but it has been disputed by some (as well as supported by others) that the conditions of production in many, or most, of these cases are to be found in nature.

Although I am not justified in discussing points in these theories which have already been so concisely reviewed by Mr. Medlicott in the paper quoted above (*ante*, p. 93), I may call attention to an interesting series of results laid before the Chemical Society on June 19th, 1884, by Drs. Armstrong and Miller. These authors carefully investigated the effect of high temperatures on petroleum-hydrocarbons, and one of the conclusions to which they arrived was that the benzenes are products in a direct line of the action of heat upon the paraffins and not, as hitherto supposed, built up from hydrocarbons of the acetylene series. This conclusion bears most directly upon the conclusions of Berthelot and his successors.

A further point upon which recent researches have thrown a great deal of light might also be noticed here. The impermeability of clays, limestones and other rocks has been urged, by Sterry Hunt and others, as an argument in favour of the indigenous origin of petroleum. Mr. Medlicott, in noticing this point, says (*loc. cit.*, p. 191), "When we find geodes filled with successive layers of minerals in the midst of compact basalt, it is difficult to place limits upon the possibilities of permeation," an objection which has been greatly confirmed by other and more conclusive evidences in the recent studies of rock-metamorphism. In 1885, and since that year, Professor Judd has accumulated a large amount of evidence from experiment and observation to prove that, in deep-seated rock-masses, liquids can both penetrate and, along certain definite directions, effect the solution of minerals, with the production of isolated or connected negative crystals, which become afterwards infilled by various solids to produce the schiller appearances now being widely recognized in crystals.[5] A most striking case of this nature occurs in the well

[1] *Loc. cit.*, p. 208.

[2] *Ann. Chem. u. Pharm*, vol. cxv, p. 21.

[3] *Ber. Deutsch. Chem. Ges.*, vol. xix, p. 349.

[4] *Ibid.*, vol. xx, p. 596.

[5] *Quart. Journ. Geol. Soc.*, vol. xli (1885), pp. 374-389; *Mineralogical Magazine*, vol. vii (1886), p. 81, and subsequent papers.

known "Apatitbringer," of Oedegaarden, near Bamle, in which Professor Judd showed that plagioclase-crystals, by a process to which in the same year he gave the name of *statical* metamorphism,[1] become first infested in this way with sodium chloride solution, and then by dynamic action become transformed into scapolite.[2] I have only quoted these cases as examples of many proofs (by numerous other authors as well) to show that the so called impermeability of deep-seated rocks by liquids lends no support to the notion that petroleum is indigenous to the rocks in which it is found.

APPENDIX.

Bibliography *of the* Petroleum resources *of the* Punjab *and* Baluchistan area.[3]

1835. PIDDINGTON, J.—Examination of a mineral exudation from Ghazni. *Journ. As. Soc. Beng.*, Vol. IV, p. 696.

1836. „ *Bibl. Univer.*, Geneva, p. 173.

1841. WOOD, J.—A personal narrative of a journey to the source of the River Oxus by the route of the Indus, Kabul and Badakshan, performed under sanction of the Supreme Government of India in the years 1836, 1837, and 1838. London, 1841, 144 pp. (and new edition, 1872, 91 pp.).

1842. VIGNE, G. T.—Rock-oil near Derabund, Kabul, p. 61.

„ „ Travels in Kashmir, Ladak, Iskardo, the countries adjoining the mountain-course of the Indus, and the Himalaya, north of the Punjab, Vol. II, p. 305.

1843. JAMESON, W.—General observations on the Punjab and on the Geology of the Salt-Range and part of Afghanistan. *Journ. As. Soc., Beng.*, Vol. XII, p. 193.

1846. HUTTON, T.—Notes on the geology and mineralogy of Afghanistan. *Cal. Jour. Nat. Hist.*, Vol. VI, pp. 564 and 601.

1847. ABBOTT, J.—Extracts from a letter descriptive of geological and mineralogical observations in the Huzaree district, Camp Puhli, in Huzaree, 19th June, 1847. *Journ. As. Soc., Beng.*, Vol. XVI, p. 1137.

1848. FLEMMING, A.—Report on the Salt-Range and on its coal and other minerals. *Journ. As. Soc., Beng.*, Vol. XVII, pt. II, p. 517.

1853. „ Report on the geological structure and mineral wealth of the Salt-Range in the Punjab. *Journ. As. Soc., Beng.*, Vol. XXII, pp. 265 and 347

1854. THEOBALD, W.—Notes on the geology of the Punjab Salt-Range. *Journ. As. Soc. Beng.*, Vol. XXIII, p. 669.

1857. THORNTON, E.—Gazetteer of India—Kohat, p. 509.

1862. MACLAGAN, R.—*Government Gazette*, Feb., pp. 23 and 28.

1866. FENNER, A.—Punjab oil, *Proc., Punj. Govt., P. W. D.*, June 17th.

1867. BROWN, DR.—*Supp. Punj. Govt. Gaz.*, 7th Feb.

„ OLDHAM, T.—Memorandum on the results of a cursory examination of the Salt-Range and parts of the districts of Bunnoo and Kohat with a special view to the mineral resources of those districts. *Sel., Rec., Govt. Ind.*, Vol. LXIV, p. 780.

[1] *Geol. Mag.*, dec. iii, vol. vi (1889), pp. 243-249.

[2] *Min. Mag.*, vol. viii (1889), pp. 186-198, and plate ix.

[3] In compiling the bibliography the petroleum-resources of this area, which is now being more thoroughly surveyed, I have sought especially to bring together original observations which may be of value to present workers in the field. At the same time, for the general traveller or commercial adventurer I have given a large number of references which are principally abstracts or summaries of original publications, and which may in some cases be the only literature available, an occurrence not infrequent in this country.

For the sake of uniformity, I have followed the abbreviations used in Mr. R. D. Oldham's excellent "Bibliography of Indian Geology" (Calcutta, 1888). References not occurring in that work are given sufficiently clearly to dispense with explanation.

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Note *on the* Geology *of the* Lushai Hills, *by* TOM D. LA TOUCHE, B.A., *Deputy Superintendent, Geological Survey of India.*

The geological examination of the Lushai Hills made by me during the military expedition of 1889-90 was practically limited to the immediate neighbourhood of the road constructed by the troops between the valley of the Kurnafuli at Demagiri and the Myit-tha valley in Upper Burma; the density of the jungle, especially in the western part of the hills, rendering it almost impossible to leave the road for the purpose of making observations, and the character of the inhabitants preventing my doing so without an escort; and as it was but seldom that detached parties were sent to any distance from the main line of advance I had few opportunities of visiting places lying to the north or south of the road.

Since, however, the road crossed all the ranges lying between the two valleys above mentioned, and the strike of the rocks corresponds almost invariably with the direction of the ranges, that is, nearly due north and south, I was enabled to form a very fair idea of the rocks composing the hills throughout their whole width from west to east, the cuttings along the road greatly assisting me; while a close examination of the pebbles brought down by the larger rivers, which, as may be seen from a glance at a map of the country, run for great distances in a direction parallel to that of the main ranges, afforded some indication of the rocks to be found in their drainage areas to the north or south of the road.

The results of my investigations were altogether disappointing, so far as the expectation of finding useful minerals in these hills is concerned: neither in the rocks traversed by the road, nor in the débris brought down by the rivers, did I find traces of coal, limestone or other minerals of economic value; at least until the valley of the Myit-tha was reached. There a few large masses of concretionary limestone were found in the bed of the Kyounka stream west of Myintha; and in the hills to the east of the Myit-tha between Kyaukpyauk and Indin, considerable beds of nummulitic limestone, which may prove useful in the Chindwin district, were also found.

The whole mass of the Lushai Hills, on the line traversed, consists of sandstones and shales of tertiary age, thrown into long folds the axes of which run in a nearly north and south direction: the surfaces of the sandstone beds frequently show fine examples of "ripple marking," denoting that they were probably laid down in comparatively shallow water; indeed, the whole character of the deposits is such as to render the supposition probable that they were laid down in the delta and estuary of an immense river issuing from the Himalayas to the north-east of Assam during tertiary times and flowing due south through the country now occupied by the Naga and Lushai Hills. Only in one place did I find any fossils: these occurred in some rather nodular dark grey sandstones, cut through by the road where it runs along the top of a precipitous scarp between Fort Lungleh and Teriat. These fossils have not yet been properly examined and determined, but there is no doubt that they are marine, or perhaps estuarine, and their *facies* seems to correspond with that of the fossils found in the sandstones overlying the nummulitic limestone of the Garo and Khasia Hills in Assam. Whether it would be possible, by a more detailed examination of the rocks than I was able to make, to correlate the various portions of this monotonous succession of sandstones and shales with the divisions of the tertiary strata in other districts, I cannot say, but without more fossil evidence it would be a difficult task, and, considering the entire absence of any minerals of economic value, a most profitless undertaking.

After passing the deep gorge of the Koladyne river, and the Tao Klang, there is a marked change in the aspect of the hills as we proceed eastwards: instead of the dense bamboo jungles and rank undergrowth characteristic of the western ranges, we find open grass-covered slopes, with groves of oaks and pines (identical with the well-known *Pinus Khasiana* of Assam) interspersed with rhododendrons. This change in the scenery and vegetation does not appear to be accompanied by any corresponding change in the composition of the rocks, but is more probably due to a diminished rainfall in the eastern hills, and to their greater mean elevation.

The peculiar orography of these hills is a subject that deserves some notice, but, in the absence of more detailed maps, is one that cannot now be fully discussed. It is also of some practical importance, for, this being the shortest route from India to Upper Burma, it would, naturally, were the configuration of the hills other than what it is, be the most favourable for a railway. As it is, it would be difficult, I think, to find a country more unfitted by nature for the carrying out of any project of the kind, for not only do the ranges and river gorges run directly transverse to the direction in which it is desired to carry the railway, but the character of the rocks and climate is such that landslips would necessarily be frequent in the heavy cuttings that would be required on the whole length of the line, and the expenditure on its maintenance, even supposing it were constructed, would be enormous.

Report *on the* Coal-fields *in the* Northern Shan States, *by* FRITZ NOETLING, PH.D., *Palæontologist, Geological Survey of India.*

PREFACE.

The present report on the survey of the coal-fields in the Northern Shan States does not pretend to be exhaustive in every respect, and, until further information is obtained, it must be considered merely as the result of a preliminary investigation of the coal-fields existing between the Irrawaddi and the Salween. I am sorry to say that the report is greatly deficient in geological observations. There are no detailed sections, such as I was able to describe in my report on the Chindwin coal-fields; observations regarding the strike and dip of strata are even more scanty, and, lastly, I have not been able to ascertain the relations between the different localities where the coal-seams were found outcropping.

The absence of these desiderata is chiefly due to the nature of the country and to the want of accurate maps on a large scale. The peculiar way in which the seams outcrop is, of course, most fatal to an exact examination. The seams are only to be seen in the beds of the streams and along their steep banks; any swelling of the streams, even if it be only for a few inches, may therefore completely concea the outcrops. The banks along which good sections could fairly be expected are steep and covered with impenetrable jungle, so that only here and there, where the last floods have carried away the vegetation, observations of the strata hidden under the surface soil can be taken. As will be seen further on, the coal-bearing formation has suffered an extensive superficial destruction by which large parts of it were removed, while it is also extensively obscured by thick layers of clay or gravel being deposited on the top of it. It is now only at such places, where the course of the present streams has cut deep enough through the hiding cover of clay or gravel, that coal-bearing strata may be expected to outcrop.

In cases like this the want of boring plant makes itself conspicuously felt. For instance, at one place I noticed a big seam of about 30 feet in thickness in the bed of the stream, and although large side-cuttings were made, they did not reveal much as to the way in which the seam was deposited. At another place, lying in the direction of the supposed continuation of this very seam, I noticed the outcrop of a seam, evidently of great thickness, which, however, equally exhibits little as to bedding. Now do these two outcrops belong to the same seam, or do they represent two different seams? The probability is that they belong to one and the same seam; but this is only guess-work, as between the two localities the alluvial deposits hide the older strata completely. Three bores, of probably not a very great depth, would have ascertained whether the outcrops belong to one or to different seams, whether they are only pockets locally swollen up to a large thickness, or whether this thickness prevails throughout the seam.

A careful combination of isolated facts has, however, enabled me to form a general idea about the coal-fields and their value, though it may not be strongly supported by detailed sections.

As regards the maps, those published at present are accurate and detailed enough for general purposes, but a geologist requires for his delicate observations a map on large scale, which will enable him to fix his position with an accuracy of about 50 feet. A reliable map on a large scale means frequently half of the geological work already done, because the features of the surface often enough reveal to the trained eye their internal structure. With the assistance of a reliable map and by combining certain geological facts noticed by him, any experienced geologist will be able, with a certain amount of certainty, to draw his conclusions as to the extension and development of strata at places, even though he may not have visited them. The want of a reliable map is also most seriously felt when it is necessary to estimate the area throughout which the valuable minerals are to be found, and it is with regard to this that my report again lacks accuracy. I may know the point up to which the seams extend with absolute accuracy, but I am unable to fix it on the map owing to the blank space shown there, where hills and streams should be marked. The estimates as to the area over which the coal-fields extend will therefore be only approximate, but I believe them to be rather under the mark than above it.

To sum up. This report should only be considered as a preliminary description of certain coal-fields in the Northern Shan States. It is likely that it will have to be modified in details afterwards. I give, however, a certain number of facts which will enable the reader to judge for himself as to the probable value of the coal-fields, provided that he will accept my view.

I have considered it advisable to divide the report into two parts: the first, a general part which will give a topographical and geological outline of the country between the Irrawaddi and the Salween from about Lat. 22° to Lat. 23°; while the second part will deal with the particulars of the coal-fields.

PART I.

SECTION I.—TOPOGRAPHICAL SKETCH OF THE COUNTRY EAST OF MANDALAY BETWEEN THE IRRAWADDI AND THE SALWEEN.

(*a*) *General topographical features.*—The hilly country east of Mandalay that rises rather suddenly from the alluvial plains of the Irrawaddi is generally known as "The Shan plateau" or "The Shan hills." The term "plateau" does not, however, exactly suit this country, as although the marginal crest, when seen from the plains, seems to form a nearly horizontal line indicating a perfect plain, the country itself is very much intersected by deep valleys. The term "Shan highlands" would be much more fitting, but as in a geological sense the country still forms a "plateau," although very much changed in its features, the term of "Shan plateau" may still be used, with the restriction, however, that it should apply only to the country south of the great Gôkteik-Kunlôn valley. As frequently noticed with plateaux, the highest elevations are found along the outer margin facing the Irrawaddi plains. The highest peak rises to nearly 5,000 feet (4,714); the average height of the crest may be 3,000 to 3,500 feet; the plateau slopes very slowly to the east for a distance of about 20 miles as the crow flies, till it reaches its deepest in the Thônzè valley with 2,339 feet near the village of Kônza. On the eastern side of this valley the country rises again to a height of about 3,000 feet, seemingly forming a hill range running from north to south. This hill range is, however, only the western slope of a second plateau slowly falling to the east, and this feature of a steep slope facing west and a gradual dip to the east is several times repeated in the country lying east and south of the Gôkteik pass. As a result of this formation all the chief valleys run in a direction nearly north and south.

The country north of the Gôkteik-Kunlôn valley cannot be described as a plateau owing to various systems of hill ranges. It is very difficult to say whether these predominate in any one direction. It seems, however, that the direction from west to east of the main ranges was the original one. The direction of the valleys does not show the regularity of the southern part, none being more general than the others.

It will therefore be seen that the tracts north and south of the Gôkteik-Kunlôn valley are perfectly different as regards their topographical features, and I shall further prove that this is in a great measure due to their different geological constitution.

(*b*) *The Gôkteik-Kunlôn valley.*—The boundary which separates the plateau-like south from the hilly north of the country here described is marked by a long valley which begins a few miles east of the Gôkteik pass and runs in a north-eastern direction to the Salween, and probably far beyond it towards Western China. This valley has the peculiar feature that it has not one general direction of drainage but three, at least so far as I have examined it. Beginning from the Salween, we see the water running to the east up to a village called Hoika about 30 to 35 miles east of Lashio. Beyond that village the water runs to the west as far as Bawgyo, where it is met by a stream coming from the west, joining the waters coming from the east. This irregularity—the direction of drainage—proves that the origin of this valley must be a peculiar one, and so it is. The Gôkteik-Kunlôn valley marks a line of great disturbance of the strata; two large faults, or probably two systems of compound faults, running from the south-west to the north-east, are distinctly discernible. Along these faults the country was thrown down, but as this action did not of course take place very regularly, one part moving perhaps stronger than another, the peculiarity of the drainage system is readily explained. It is very common in this valley to meet isolated hills rising abruptly in its centre; they are nothing more than small parts of the sinking blocks which have become jammed. Sometimes they still touch both sides of the valley, forming a kind of bar or ridge. Such bars, breaking seemingly the continuity of the valley, are numerous and of smaller or larger extension, and they account also in some degree for the direction of the drainage. A most perfect instance of such a bar may be seen between the villages of Manpeng and Meungyaw. Here the bar has a length of about 5 miles; the breadth may be about the same. The bar consists of red sandstone, resting on blue limestone, while the hills on both sides are formed of blue limestone. Thus the lateral boundary between red sandstone and blue limestone is as distinct as possible, proving plainly the existence of a fault on either side of the bar. Similar bars may be seen east and west of Lashio, but I have never noticed them so clearly discernible as in the instance quoted above.

The direction of the faults is distinctly marked, on the map of Upper Burma (scale 1 inch = 4 miles, sheet No. 4, south-west), by a series of precipices running parallel on either side of the Gôkteik-Kunlôn valley in a direction from south-west to north-east. On the map these precipices are shown as short hill ranges. This is, however, not quite correct, as these "ranges" have only one slope, or, better, precipice, facing the valley. I stated above that I believed there is a system of compound faults. The reasons which make me think so are that there are several of these precipices following each other in the directions towards the centre of the valley. The rise towards the plateau therefore goes in steps, and it is evidently a system of step faults that produced this feature of the country, the precipices representing the fault scarp on both sides of the valley. Of course this does not take place all along its length, but it can be well seen on the northern side between Bawgyo and Thibaw.

Valleys similar to the Gôkteik-Kunlôn valley will be met within the Shan plateau, although they are not of as great importance as it is; such valleys are the Namma valley, a part of the Myitngè valley, and others.

(*c*) *Two systems of valleys.*—There are therefore two systems of valleys, the first one running from north to south, the second one running from south-west to north-east. While the direction of drainage is always to the south in the first-named system it does not always keep to one direction on the second system. It is rather difficult to say which of the two systems is the older one, but considering that the second system contains strata which, so far as I know, are not found in the valley of the first system, and that whenever a valley of the first system crosses one of the second system, the first one is thrown off its direction, I consider the east-western system to be the older one. There are, however, further proofs required and I give this theory with every reservation.

SECTION II.—GEOLOGICAL OUTLINES OF THE COUNTRY BETWEEN THE IRRAWADDI AND THE SALWEEN.

The strata taking part in the composition of this country belong to the following formations:—

1. Gneissic formation.
2. Submetamorphic formation.
3. Palæozoic formation ranging probably from the cambrian to the upper silu rian system.
4. Red sandstones of undetermined age.
5. Tertiary formation, probably younger miocene.
6. Alluvial formation, including river deposits and hill clay.
7. Volcanic rocks: Porphyry of unknown age, granite of gneissic age.

The limestones of the palæozoic prevail, and then follow the shales of the submetamorphic formation. Of inferior importance is the gneiss; while the red sandstones and the strata of tertiary formation, such as sandstones, clays, and coal-seams, are only locally developed. The alluvial deposits may be found anywhere where there is room left, the hill clays taking the prominent part. Of the volcanic rocks, the granite is only found in the north; the highly interesting porphyry is only known up to now by pebbles from the Namma stream.

1. *The Geissic formation.*—The gneissic formation is particularly developed in the northernmost part of this territory in the Mainglôn State and along the frontier of the Ruby Mines district. Its mineralogical composition shows evidently the character of the Himalayan gneiss, being of white or greyish colour, the common felspars being orthoclase and albite. The same gneiss is again met with at the outskirts of the Shan plateau near Kyauksè, where it forms thick beds. Here it is associated with mica schists. Gneiss is also found along the right bank of the Irrawaddi in a small band extending from Sagaing to the north. In the Mainglôn State, as well as near Kyauksè, the gneiss seems to be associated with eruptive granite. It is, however, not quite certain whether the granite is true eruptive granite, although from the way in which it occurs this seems very probable.

2. *The Submetamorphic formation.*—The submetamorphic formation is, as far as I know, only developed in the northern part of country here to be dealt with. It seems, however, that its southern boundary is not far from the northern fault limiting the Gôkteik-Kunlôn valley. The peculiar topographical features of the country north of the line just mentioned seem therefore to be chiefly due to the nature of the gneiss and shales which are developed here. The strata belonging to the submetamorphic formation consist of blue or greenish shales containing frequently veins of white quartzite (? fault-rock), of somewhat honeycombed appearance. The bulk of the quartzite pebbles met with in the gravels of the plains seems to me to originate in the destruction of these quartzite veins.

3. *The Palæozoic formation.*—The palæozoic formation is of very large extension in the country east of Mandalay. Most probably the isolated hills rising from the plains belong to it, although they are very much metamorphosed. It certainly begins at the foot of the hills and extends from there to the east as far as the Salween, and since the Trans-Salween hills have the same appearance as those to the west of it, we may fairly conclude that it extends further still beyond the Salween. Its northern limit is roughly marked by the northern slope of the Gôkteik-Kunlôn

valley, although both sides are formed by it. How far it extends to the south is not known at present. If, however, the limestone hills east of Moulmein are of the same age as those near Mandalay, the palæozoic formation has a considerable extension into Indo-China.

The strata consist of limestones only, and dark blue colours are prevalent; scarcer are greyish, green, and red limestones. According to their position I am able to distinguish two groups for the present, namely,—

(*a*) The lower group: Mandalay limestone without fossils.

(*b*) The upper group: Pyintha limestone with fossils of lower silurian age.

(*a*) *The Lower group, or Mandalay limestone.*—The Mandalay limestone forms the foot of the Shan hills; and very likely some of the isolated hills rising from the plains belong to it. It is of a dark blue colour, bedded in thickish layers and seemingly without fossils. Along the outskirts and in the plains, the Mandalay limestone is very much metamorphosed. In the plains it is changed into a white crystalline limestone which is traversed by numerous runs of fault-rock and an eruptive rock, the nature of which can only be determined by microscopical examination. Along the western slope of the Shan plateau the Mandalay limestone has also suffered another kind of metamorphosis by pressure. This pressure has perfectly crushed the rock to small fragments, which became again cemented by the deposit of white crystalline limestone. The limestone is thus traversed by numerous fine white veins which produce a very good effect on the black background, and I should therefore think it would do very well for ornamental purposes. A distinct zone of about 2 miles in breadth of such breccia limestone can be noticed along the western slope of the Shan plateau.

(*b*) *The Upper group, or Pyintha limestone.*—The Pyintha limestone is only well seen between the 22nd and 26th miles on the road from Mandalay to Maymyo. It consists of grey, greenish grey, reddish grey, and red limestones, frequently rather clayey. It is bedded in thinner layers than the Mandalay limestone, and breaks into fine big flags. I was fortunate enough to discover a small fauna in this limestone, about which I have already published a short notice in the Records of the Geological Survey of India for 1890, (Vol. XXIII, p. 78).

The following fossils were collected:—

Crinoidarum, gen., isolated links and fragments of the stem; belong evidently to two different species.

Echinosphærites kingi, spec. nov., a gigantic species of this well-known genus of the lower silurian group.

Orthoceras sp. cf. *regulare*, in numerous fragments.

Although the specimens were very much disfigured by pressure, they were quite sufficient to determine the age of this limestone, proving it to belong to the silurian formation, more particularly to the lower silurian one. As the echinosphærites limestone of Northern Europe ranges close to the basis of the lower silurian group, we may fairly surmise the same age to be that of the Pyintha limestone. Now, as the Pyintha limestone certainly rests on the Mandalay limestone, the latter must necessarily be of an earlier age, and, being of a considerable thickness, it may be supposed that it represents the equivalent of the cambrian formation. Unfortunately I was not able to examine the strata which followed the Pyintha limestone, the ground being not very favourable for a considerable distance, when there were again some cuttings along the road. A blue limestone of similar nature to the Mandalay limestone was noticed, and the same limestone was found as far as the Salween. Though I searched carefully, I did not discover a single fossil. Now, it is difficult to say whether this blue limestone is of the same age as the Mandalay limestone, or whether it represents a younger group. Only detailed examination extending over a large area and for a long time will settle this question.

4. *Red sandstone of undetermined age.*—As far as I know at present, the red sandstone is only found in the Gôkteik-Kunlôn valley, namely, east of Thibaw and in the neighbourhood of Lashio. It rests on the blue limestone, but whether conformably or not I could not ascertain. No fossils have been discovered in this series of strata, and it can therefore only be said that they are of post-silurian age.

5. *Tertiary formation.*—It is certainly very remarkable that from the long series of strata which lie between the silurian and the tertiary epoch, no other traces could be found but sandstones the age of which is very doubtful. If they should prove to be of palæozoic age, the whole of the mesozoic group up to the most recent tertiary beds would not be represented in this part of the Shan hills, and we are therefore led to believe that either the once existing mesozoic strata have all been washed away, or that the present Northern Shan hills form part of an old continent which was laid dry at a very early epoch. The present Shan plateau forms now only the remnant, so to say, of a once mountainous country, the mountains, however, having all disappeared, shaved off apparently by marine denudation, and it is most likely that the Shan plateau formed up to tertiary times a continent. Further examination, particularly to the south, will prove whether there is any substantiality in this theory.

The tertiary strata are, as far as at present known, only found in the valleys belonging to the second system, *i.e.* those valleys which run from south-west to north-east. As these valleys, however, originated by the downthrow of a part of the strata along a system of parallel faults, it is clear that the tertiary strata must once have been at a higher level than they now are; provided that it cannot be proved that they have been formed locally, namely, at the very same place where they are found now. If the first theory is found to be correct, the tertiary strata must formerly have had a larger extension. They were, however, nearly totally destroyed, and only those parts were saved which were thrown down from their original level. Should they, however, have been deposited locally, it cannot be expected that they will have a large extension. Although this question seems to be of only scientific value, it has a most important practical side when we come to estimate the extension of these coal-fields. As regards the Lashio coal-fields, the facts are not strong enough to disprove absolutely the theory that they are only local deposits, but as regards the Namma-Manzè coal-fields, the observations are strongly in favour of the downthrown block theory; that is to say, that the present coal-fields form only part of beds, once more extended, which have been preserved by sliding down in a kind of trough in which they now form the core. It is, therefore, also possible that the Lashio coal-field is of the same origin. This theory being admitted, it will give valuable hints where to look for further coal-fields; it is in the valleys of the second system that they may be expected, neither on the heights of the plateau nor in the valleys of the first system. Subsequent examinations will be necessary to produce further proof, but whatever is known at present about the different coal-fields in the Northern Shan States seems to support this theory.

As regards the age of the beds, they are apparently of late tertiary age. The strata in the Lashio valley are different to those I have seen in the Chindwin. The strata in the Namma valley, however, resemble those found in the Chindwin. The fossils which have been found, the numerous fragments of a small *Planorbis*-like snail and another big gastropod, are too insignificant; they are, besides, so much disfigured by pressure, that it will be impossible to identify them. The question of the age of the Shan coal-fields must for the present remain open, until further more significant fossils can be found. For the present it can only be said that they are probably of late tertiary age.

The strata consist of sandstones, clay, and coal seams. The sandstones are finely grained, of white or yellowish colour, rather soft. They should, however, form a good roof; the clays are grey or brown, easily softened by water.

The coal occurs in beds of various thickness, from 2 inches up to 30 feet; thin seams are not frequent. The average thickness of the seams in the Namma coal-field is 5 to 6 feet; in the Lashio coal-field even higher still. It is very difficult to give an estimate of the total number of seams for the reasons which I explained in the preface; for instance, it is not quite settled yet whether in the Lashio fields there is only one or two big seams, or whether there are several seams. In the Namma coal-field the probable number may be 10 to 12 seams. At least I was able to distinguish that number of different seams. It is, however, not unlikely that there are more still. The aggregate thickness of coal in the Lashio field is certainly more than 30 feet, in the Namma field about 50 feet. Nothing is known for the present about the other fields.

As regards the physical structure and chemical qualities of the coal, I shall discuss them according to 12 assays, of which 11 were made by the Chemical Examiner in Rangoon, and one in the Laboratory of the Geological Survey at Calcutta. The following table will give the results of this analysis:—

No. of sample.	Description.	Moisture only, assayed in the Calcutta laboratory.	Volatile and moisture.	Fixed carbon.	Ash.	REMARKS.
1	Coal from Lashio, dull colour, very brittle.	...	66·75	24·05	9·20	Burns readily; ash reddish.
2	Coal from Lashio, probably different seam from No. 1 seam.	...	54·48	35·44	10·08	Burns readily; ash reddish.
3	Coal from Naleng (Lashio coal-fields)	21·30	33·18	33·06	12·46	Does not cake, not with vapour even; ash dark red; contains much iron pyrites.
4	Coal from Namma seam (No. 1), of bright colour, but rather friable.	...	56·82	38·58	4·60	......
5	Coal from Namma seam (No. 2), of bright colour, but rather brittle.	...	52·59	37·64	9·77	Average with intervening earth matter.
	Coal from Namma seam (No. 3), of bright jetty colour, hard but laminated, best sample.	...	60·45	36·15	3·40	Fracture glistening.

No. of sample.	Description.	Moisture only, assayed in the Calcutta laboratory.	Volatile and moisture.	Fixed carbon.	Ash.	REMARKS.
7	Coal from Namma seam (No. 4), of bright colour, but rather brittle.	...	58·37	33·47	8·16	
8	Coal from Namma seam (No. 5), of bright colour, laminated, and brittle.	...	56·08	34·08	9·84	
9	Coal fron Hoetanpaipa, on the Namma stream, of bright colour, a little friable.	...	53·49	35·12	11·39	
10	Coal from Namsale, a tributary of the Nampong, dull-looking coal.	...	53·71	31·69	14·60	
11	Coal from Manzè seam (No. 1), of bright colour, very brittle, 6-inch seam.	...	53·60	34·22	12·18	
12	Coal from Manzè seam (No. 2), dull-looking, brittle, 3-inch seam.	...	55·42	34·94	9·64	

From this table it will be seen that nearly all the samples of coal, except sample No. 1,* have a remarkable conformity of composition. As regards the percentage of fixed carbon; sample No. 4 gives the highest percentage with 38·58, sample No. 10 the lowest with 31·69 the difference being not more than 6·89, the percentage of ash varying little more. Unfortunately nothing can be said about the percentage of volatile matter, because the Rangoon assays include moisture. Now, as all the samples came from seams exposed in river-beds, it would not be quite correct to draw conclusions from these figures. They show, however, also a great conformity, and, if we assume a percentage of moisture of 20 to 21 per cent. as proved by the Calcutta analysis, we find also a great conformity amongst the samples as regards the volatile matter, and we further see that the percentage of fixed carbon and volatile matter is nearly the same.

Sample No. 1 seems to have an exceptional composition which rather differs from that of the rest. The high percentage of volatile and the low percentage of fixed carbon is remarkable. As this sample has been taken from the 30-feet seam, a few words must be said about its composition, as in my opinion it does not represent the normal composition of the seam. This had been under water for a long time, and when I visited the outcrops, it had just got dry. This would account for the high percentage of water. I should therefore think that samples obtained from a better outcrop, or, further away from the river, would show a smaller percentage of moisture and therefore a higher percentage of fixed carbon, and thus agree in general composition with the other samples. If we take the average of the 11 analyses from Nos. 2 to 12, the Shan coal will show the following composition :—

Volatile matter (including moisture)	55·40	{ Moisture 21 Volatile 34·40
Fixed carbon	34·94	
Ash	9·67	
TOTAL	100·01	

The coal is therefore, comparatively speaking, of poor quality, and can hardly be called "coal." The term "lignite" or "brown coal" would better express its composition.

As regards its physical qualities, the Shan coal has rather a low specific gravity, when not mixed with iron pyrites. If it is not disintegrated by the water, it is hard, and has a bright, dark brown, nearly black colour (in several samples the colour is black), the fracture is glistening, and it breaks in big lumps. If, however exposed for some time to water and air, the colour gets dull, earthy looking, and owing to its lamellar structure and to the cleavage the coal readily disintegrates into small, prismatic fragments.

It may therefore be said that the Shan coal, when fresh, would make a very good fuel, and that, being rather hard, it would stand a long transport. The coal of those seams, which owing to their friability could not be well transported, should make an excellent material for patent fuel.

The following table of analyses gives the composition of coal from Raniganj, Karharbari, Assam, Upper Chindwin, Namkongchaung above Mogaung, Thigyit near Nyaungwe (Southern Shan States), and the average composition of Shan coal:—

Description.	Volatile including moisture.	Fixed carbon.	Ash.	Remarks.
India, Raniganj coal	32·65	51·08	16·27	Not stated whether volatile matter includes moisture or not.
India, Karharbari, average of 16 analyses.	24·01	63·66	12·33	
India, Assam	36·20	60·00	3·8	
Burma, Upper Chindwin, average of 11 analyses.	44·73	49·95	5·30	Moisture . 10·14; Volatile, excluding moisture . 34·59
Burma, Namkongchaung near Mogaung	52·67	35·98	11·35	Moisture not separated from other volatile matter.
Burma, Mantha, opposite, Thabetkin, Upper Irrawaddi.	42·76	34·08	23·16	Moisture . 9·20; Volatile matter, excluding moisture . 33·56
Burma, Shan States, Palaung coal-field, east of Hlaingdet, average of 8 analyses.	21·15	65·81	13·01	Moisture . 4·29; Volatile matter, excluding moisture . 16·86
Burma, Shan States, Legaung coal-field, east of Hlaingdet, average of 2 analyses.	14·58	70·43	14·99	Moisture . 2·08; Volatile, excluding moisture . 12·50
Burma, Shan States, Thigyit, near Nyaungwe.	59·00	30·26	10·78	Moisture . 22·74; Volatile, excluding moisture . 36·26
Burma, Shan States, Lashio, and Namma coal-field, average of 11 analyses.	55·40	34·94	9·67	Moisture about . 21·; Volatile matter, about . 34·40

From this table it will be seen that the coal of the fields in the Northern Shan States is very much poorer than that of the fields in the Southern Shan States; while in the latter the percentages of fixed carbon are 65·81 and 70·43 respectively, it is in the former not more than 34·94, the percentage of volatile matter and moisture being also much smaller. The coal of the Southern Shan States would therefore be much preferable to that of the Northern Shan States, provided there were a sufficient quantity of it. The late Mr. Jones says, however, in his report on the Palaung coal-field (Records of the Geological Survey of India, Volume XX, Part IV, 1887, page 185), "I did not see a single seam which held out any real prospect of being workable. The seams are exceedingly irregular, that is to say, they are not to be depended upon to extend to any distance. A large proportion of the coal consists of mere pockets." This is by no means an assuring prognostic. The coal seams in the Northern Shan States are more favourably deposited, and, being found in workable quantities, they could be depended upon for the supply of fuel to any railway through the Shan States, although they are of inferior quality.

The Indian coal, as far as regards the three localities above mentioned, is certainly superior to the Shan coal, but the average Chindwin coal does not differ so much, volatile matter and ash being nearly the same, and fixed carbon 15·01 more than in the Shan coal.

If we only take the percentage of fixed carbon for comparison, the equality of the Mogaung, Mantha, and Lashio-Namma coal is most startling, the figures being 35·98, 34·08, 34·94 respectively. The Mantha and Lashio-Namma coal differ, however, considerably as regards the percentage of ash and moisture, while the percentage of volatile matter again agrees. If the whole composition is taken into consideration, the similarity of the Mogaung coal and the coal from the Northern Shan States is really surprising, as will be seen from the following table:—

	Mogaung coal.	Coal from the Northern Shan States.
Volatile matter including moisture	52·67	55·46
Fixed carbon	35·98	34·94
Ash	11·35	9·67

Can this similarity of composition be an indication that coal-fields of nearly the same age as those of the Northern Shan States are developed west of the Irrawaddi in the Mogaung district; and, if so, do these strata extend across the Irrawaddi, and are there coal-seams of any larger extension in the country to the north of the coal-field here described. These are questions of no small importance which, however, can easily be settled by actual examination in the field. The last analysis is that of lignite, Thigyit. It will be seen that, although it is poorer in the percentage of fixed carbon, it certainly belongs to the same group as the Lashio and Mogaung coal.

6. *Alluvial deposits.*—The alluvial deposits are found everywhere where there is a favourable place for their deposit. The river deposits, such as conglomerates, gravels, and sands, are of course limited to the valleys, while the clays may be found in the valleys, as well as on the top and slopes of the hills. According to their origin, we may distinguish two kinds of alluvial deposits:—

(*a*) deposits resulting from the superficial disintegration of the rocks; hill clay;

(*b*) deposits resulting from the débris of rivers, conglomerates, sand, river clay, and silt.

(*a*) *The hill clay.*—The hill clay is found everywhere in the Shan plateau. It is evidently the results of the disintegration of the limestone *in situ*, and as such covers the limestone with a coat of varying thickness. It is a red, tough clay, which, by being washed down to the valleys, contributes largely to the deposit of river clay.

(*b*) *The river deposits.*—The river deposits are found everywhere in the valleys where there is a favourable place for their deposit. They are worthy of mention as being not only the matrix for precious stones, such as ruby or tourmaline, but also as concealing the coal-bearing strata in the valleys. It is only due to the thick layers of conglomerates and clays that the coal-fields have been insufficiently explored. The cap of river deposits completely hides every feature of the strata underneath, and it is only at places where the present streams have cut deep enough that the strata underneath may be examined. For this reason they will also be of importance when it comes to the exploitation of the coal-fields. We can distinguish (1) conglomerates, gravels, sand; (2) clay, not bedded; (3) well-bedded silt and clay of the Irrawaddi plains. Of these different strata, only Nos. (1) and (2) are of importance here:—

(1) *The conglomerates.*—Consist chiefly of pebbles of white quartzite or fault-rock always well rounded, in various sizes up to the size of a man's head. The Mainglôn conglomerates contain rubies and tourmaline, the conglomerates in the Namma valley quartzite porphyry. The pebbles are cemented by a clay cement containing numerous angular grains of quartzite; they thus form a compact mass which is difficult to attack by ordinary tools, but when once softened by water can readily be removed. The conglomerates locally change into gravels and sands.

(2) *River clay.*—The river clay is usually of brown or reddish colour; it is not bedded, and wherever conglomerate and clay occur together it covers the first. In the Lashio valley it lies directly upon the coal-bearing strata, where it may however be mixed with the hill clay washed down from the hills. Thus occasionally the youngest deposits of river clay are mixed with sand and gravel, as in the Namsèka ruby-mine.

7. *Volcanic rocks.*—Granite and the peculiar rock (fault-rock) piercing the crystalline limestone of the Mandalay hill have been mentioned above. A few words only are necessary regarding the curious specimens of quartz-porphyry discovered amongst the pebbles of the Namma stream near Namma village. Although only a microscopical examination can confirm the porphyritic nature of this rock, their macroscopical appearance is still that of the true quartzite-porphyry, so common in Germany. The specimens collected by me show different varieties of various composition. The source of these porphyries can be easily fixed, as the Namma stream comes from the hills to the east of that village, and the porphyry must consequently be found between Lat. 22° 30′ and 22° 35′; Long. about 98°.

Hot and saline springs.—In the Shan States, as in all other places, the great lines of disturbances of faults are accompanied by springs, either hot or brackish It is not very surprising that such springs are found in the Gôkteik-Kunlôn valley. For the present such springs are known near the following places:—

(*a*) Hot springs—
  (1) Tapong, near Lashio.
  (2) Meungli Nampong, on the way from Lashio to Thibaw.
  (3) Namhsim, near Thibaw.
  (4) Mankang, west of Meungyaw.
(*b*) Salt springs—
  (5) Bawgyo, near Thibaw.

I have no doubt, however, that several other localities remain to be discovered. As far as I have ascertained, the wells are always found on the margin of the valley just where the faults might be expected. I have not heard of wells being situated in the centre of the valley. I have visited wells Nos. 1 and 5. Spring No. 1 is situated about half a mile south-east of the old Lashio post. It comes out in a horse-shoe-shaped tank thickly filled with fine grey mud; the water is perfectly clear and of a beautiful blue colour; its temperature is up to boiling point; no distinct openings are visible from which the water issues, but bubbles of steam rise continually from the bottom. The percentage of solid matter is very small. Two samples sent to Rangoon were found to contain 0·0588 per cent. and 0·041 per cent. respectively. The salts consist of sulphate of lime and magnesia, with traces of alkalies, principally potash. It seems that the principal part of the solids is lime. This might be expected, as the spring issues from limestone rocks. Dr. Sinclair, Inspector-General of Jails, Burma, writes about the qualities of this spring as follows: "Taken in quantity it "would act as an aperient and would beneficially affect a congested liver. Internally "and externally it would probably be highly beneficial in cases of chronic rheumatism "and gout. The salts in solution have come from dolomite in all likelihood. Much "of the subsoil water of Upper Burma is similarly charged, though not to the same "extent."

About the Bawgyo salt spring I have published a special report, and from this I need only mention here that it contains 80,771 grains of solid matter per gallon of water. This solid residue is composed of the following salts:—

	Per cent.
Sodium chloride	60·30
Sodium sulphate	34·64
Calcium sulphate	1·00
Magnesium sulphate	0·86
Undetermined organic matter, &c.	3·10

Should the Bawgyo salt spring produce a sufficient quantity of brine, it could certainly be worked for salt with a great profit.

PART II.

SECTION III.—SITUATION OF THE COAL-FIELDS.

The coal-fields in the Northern Shan States which I have examined extend over a tract situated between Long. 97°45′ and 98° and Lat. 22°20′ and 23°15′ in the territories of Thibaw, North and South Theinni. Beginning in the north the following different localities representing probably so many separated coal-fields may be distinguished—

(1) *The Lashio coal-field.*—Long. 97°45′, Lat. 22°50′, near the old Chinese fort, at present occupied as a post in the valley of the Namyaw.

(2) *The Manzè-Namma coal-field.*—Long. 97°45′, Lat. 22°20′, extends in the valley of the Namma and Nampong. The above-named coal-fields have been examined, and a detailed description will be found in Section IV. Coal must, however, be rather common in the Northern Shan States, as its occurrence is reported from the following localities, which I had not time to visit:—

(3) *Theinnimyo.*—Long. 97° 45′, Lat. 23°15′. Coal is said to occur along the banks of the Namsengseik. The sample which I received from this place was, however, too small to admit of any remarks being made about it.

(4) *Namyaw Valley, near the village of Meungyaw.*—About 22 to 25 miles east of Lashio. This coal-field is apparently only the continuation of the Lashio coal-field, being situated like it in the Gôkteik-Kunlôn valley. Unfortunately I heard about the occurrence of coal near Meungyaw only when I had left the place, so I was not able to examine the outcrops. From what I have seen of the country around Meungyaw, I do not think, however, that this coal-field will have a large extension.

(5) *Mansang and Meungpat.*—Three marches east of Mansang east of the Loileng. Mansang, Long. 97° 49′ and Lat. 22° 25′, seems to be the western end of a coal-field extending to the east as far as Meungpat. As my time was limited, I was unable to visit the second locality. At Mansang only a few beds of black coaly shale were visible, and the natives stated that no further occurrence of coal near Mansang was known to them.

(6) *Nong Hswan in Kyithi-Bansan State.*—This locality does not exactly lie within the limits of the present report, being further south than Lat 22°. As I obtained some information that coal existed, I have recorded it with a view of examining it later on. The same remarks apply to the coal existing near

(7) *Silan on the Nammaw or Shwely river.*

SECTION IV.—THE LASHIO COAL-FIELD.

Longitude 97° 41′, Latitude 22° 50′.

1. *Situation of the coal-field.*—As mentioned in Section III, the Lashio coal-field is situated in the Gôkteik-Kunlôn valley, in the neighbourhood of the old Chinese fort.

Topographical features of the coal-field.—The Lashio valley is of nearly circular shape, the west-eastern axis being however the larger. It is about 3 miles in length; the smaller axis may vary from 1 mile to 2 miles. On all sides the valley is surrounded by hills, those to the north and south being however considerably higher than those to the west and east. Steep precipices run along the northern and southern hill slopes, while the ascent to the low western and eastern hills is comparatively gradual The Lashio valley is traversed by the Namyaw, which finds its way through a narrow gorge on the eastern side of the valley. It runs first along the slope of the southern hills, then turning to the north it runs for a short distance in that direction, only to turn again to the west, and run nearly in the centre of the valley: after some distance it suddenly turns to the north-east, and finally finds its way through a gorge at the north-west corner of the valley after having turned to the west again. The bottom of the valley is level only for short distances along the banks of the Nampai; generally it consists of very irregular low hills, dividing it into numerous gullies. It is of course clear that a basin-like valley like the Lashio valley which receives the drainage of the hills from nearly every side, and which has only one narrow outlet, must be turned during the rains more or less into a swamp, the water stagnating everywhere between the low hills, eventually forming marshes on which the marsh date grows in luxuriance. This surplus water, together with its natural result, the feverish climate, will, I am afraid, prove serious disadvantages to mining operations.

3. *Geology.*—The blue palæozoic limestone is the chief formation developed in the Lashio valley. It forms the hills surrounding it, and it forms the original bottom. In the east and south it is covered by the red sandstones of doubtful age. The tertiary strata cover the palæozoic strata in the bottom of the valley, and they are again covered by a layer of river clay or hill wash of varying thickness. This cover of alluvial deposits is a great hindrance to the examination of the tertiary strata, as it conceals them with a nearly impenetrable coat, and it is only at such places as along the banks of the Namyaw that the tertiary strata have been exposed. From all I have seen the surface of the tertiary beds must be very uneven, the soft strata being partly destroyed and washed away by the action of the Namyaw, which deposited in their place a thick bed of river clay. This fact, together with the impossibility of tracing the tertiary strata on the surface, renders it exceedingly difficult, if not impossible, to connect the isolated outcrops seen here and there along the steep banks of the Namyaw. Another drawback was the difficulty of fixing the exact locality of the outcrops; the only way of looking for the outcrops was by searching the banks of the river in a small boat. Now, the embankment on either side was always considerably higher than the water level and covered besides with impenetrable jungle. It was therefore absolutely impossible to say whether an outcrop, discovered after a sudden turn of the river, was connected with another one previously discovered and lying either further down or up stream.

4. *Localities of outcrops.*—The first outcrops which I visited and examined are about half a mile to the south-west of the old Chinese fort, then used as a post. The coal is exposed in the bed of the Namyaw, and is only visible if the river is at its lowest. During my stay at Lashio the river rose only about 2 feet at one time, but this was quite sufficient to conceal the whole outcrop. The seam exposed is of considerable thickness, which I measured to be not less than 30 feet. It consisted of coal throughout, the few partings being thin and insignificant. When soaked with water the coal has a bright glittering appearance, but when dry it is dull and earthy-looking. When drying it cracks just like wood that has been in the water for a long time and is suddenly exposed to the air; that is to say, big lumps of coal crack and blister superficially, but do not fall into pieces if not moved. If, however, they have to stand any kind of transport they immediately fall into small fragments. How far this quality is due to the exposure to water and air it is impossible to say. It is not unlikely that the quality will change for the better with the depth, or further away from the river. The coal contains—

Moisture and volatile matter	66·75
Fixed carbon	24·05
Ash	9·20

According to this analysis, the coal is of very poor quality; it even comes after the lignite of Thigyit, which contains 30·26 per cent. of fixed carbon. It is, however, not unlikely that just as long exposure has affected the physical, it may also have changed the chemical quality. A final decision can only be arrived at after making further trial.

The seam dips at 10° to 15° towards north-west, the strike being south-west to north-east. I tried to ascertain the nature of the strata forming floor and roof by clearing the jungle and by deep side-cuttings. Although much time and money was spent, the result was very poor. The quantity of alluvial soil to be removed would require weeks of hard work, to say nothing of the clearing of the jungle. The only fact I could ascertain was that the floor consists of a greyish blue clay.

(2) About 30 yards further on another coal-seam was, exposed of about 10 to 12 feet in thickness, the coal being of the same appearance as that of the first outcrop. Although nothing can be said about the strata between the two seams which were hidden by the alluvial deposits and thick jungle, there seems no doubt but that the two outcrops represent two different seams, direction of dip and strike being the same as in No. 1 seam.

(3) For a distance of about a quarter of a mile further up the river nothing can be seen on the bank, the jungle completely hiding the strata on both sides. At a sudden turn of the river, where the jungle had been recently washed away, the outcrop of a big seam was observed, by far the greater part of which was below the water level. The coal did not differ in appearance from the coal of the other seams. It was, however, a little brighter when dug. No exact observations could be taken as regards the direction of dip and strike. The more earthy parts of the seam contained numerous tests of fossil shells, too much disfigured however, by pressure to be of any particular value. The only species I could distinguish belonged apparently to the genus *Planorbis.* There were also fragments of another big gastropod, which could not be determined.

(4) Between this place and the bridge which crosses the Namyaw there are about half a dozen or so other places where coal outcrops, but nothing more can be said than that seams exist there.

(5) I received a sample of coal from Lieutenant Daly, which was said to come from a seam nearly equal in thickness to that mentioned under (1). The seam was said to be exposed further down the river at a place which I did not visit myself. The coal did not differ much in appearance from the coal of No. 1 seam. It may be said that it was perhaps a little harder and brighter. The analysis of this sample gave the following results:—

Moisture and volatile	54·48
Fixed carbon	35·44
Ash	10·08
	100·00

(6) Expecting that if the direction of the strike observed at No. 1 seam kept on, I should meet the same seam again on the eastern side of the Lashio valley, I took the magnetic bearing as exactly as possible, and fixed a tree near the village of Naleng as the locality where the seam ought to be found again. When I visited this place the river had unfortunately risen owing to its having been banked up further down, and the water had covered the outcrop. I could still, however, distinctly see that there was a seam of apparently great thickness in the river-bed. Messrs. Bradley and Fraser confirmed this, stating that at this very locality they had seen a big seam crossing the stream at low water. A few big lumps, which they

had taken away, were still lying on the bank. A sample of this coal had been analysed in Calcutta with the following result:—

Moisture	21·30	54·48
Volatile matter, excluding moisture	33·18	
Fixed carbon	33·06	
Ash	12·46	
	100·00	

The ash was of dark red colour, and contained a good deal of iron pyrites.

In my opinion, this outcrop forms the eastern continuation of No. 1 seam, having apparently the same direction of dip and strike. If my supposition be correct, the seam would extend about 2 miles in length.

(7) I tried to test the correctness of this supposition by looking for coal at intermediate places. The numerous gullies coming down from the north seemed to afford a good opportunity for the test, and I therefore examined them, finding, as I expected, coal in such a position that it could be looked at as part of the seam which had been observed near Naleng. I cannot exactly say whether this opinion is correct, as the outcrop was even more insufficient than those previously noticed.

5. *Stratigraphy of the Lashio coal basin.*—My first notion when I saw the outcrop of the seam mentioned above was, that the coal was, nothing more than a pocket of lignite, having been formed locally in one of the hollows at the bottom of the valley and afterwards covered with river clay, just as now-a-days the marshes are formed on the surface. Although later observations have to some extent rendered it probable that the coal was not formed locally, further proofs are still required to make this certain. It must be understood that the disposal of the local origin of the Lashio coal is of fundamental value for the future development of the coal-fields, because, if correct, the Lashio coal would be of no importance as regards the supply of fuel.

I shall proceed to weigh the *pros* and *cons* of this theory, although I must admit that it is mere speculation. The actual proof can only be obtained by borings.

The conditions which would favour a local formation of coal are as follows:—

(*a*) The basin-like shape of the valley. Such a valley with hardly an outlet was of course very favourable to the accumulation of all the vegetable matter washed down from the surrounding hills. The quantity of this vegetable matter annually washed down cannot be over-estimated.

(*b*) The surface of the sunken block, not being horizontal or even, afforded particularly favourable places for the accumulation of vegetable matter which could form a mass of considerable thickness.

The original conditions which favoured the theory of a local origin were strongly supported by the result of the analysis, which proved the Lashio coal to be of very inferior quality, it being a lignite even inferior to the Thygyit lignite.

However, after seeing the Namma coal-field, which was certainly not formed locally, and taking into consideration the origin of the Lashio valley, I did not see why a different origin should be supposed for two coal-fields which were not further away than about 30 miles as the crow flies, and which agreed in several important points. The reasons which argue against a local origin are as follows:—

(*a*) the distinct dip and direction of strike of the main coal-seams;

(*b*) the continuity of the strike, by which the locality where a seam should be found again could be pointed out before the locality was seen and examined.

As it seems that the Lashio coal was not deposited locally, but that it formed part of a region of coal-bearing strata which originally covered the palæozoic limestones and of which some parts were preserved by the sinking of a block between two faults, it will have to be ascertained whether this action affected the tertiary strata to such a degree as to disturb their continuity, so that small parts of them were jammed at different places between the socondary fault blocks of the palæozoic limestones. If this should be the case, the coal, although being parts of a once continuous seam, would now represent nothing more than kinds of pockets the extensions of which could not be depended upon. Here again only borings will enable a final decision to be given. However, from what I have said above about the regularity of strike, it seems to me certain that in one case at least there exists a seam of about 2 miles in length, even if the other seams noticed are of shorter extension.

6. ***Extension of the Lashio coal-field.***—The Lashio coal-field covers only a very limited area of 3 or 4 square miles at the utmost; and although a final decision as to the quantity of coal therein contained cannot be given, yet a rough calculation may be useful. Supposing that outcrops $\frac{2}{1}$, $\frac{2}{6}$, and $\frac{2}{7}$ form part of one and the same seam which would then have a length of about 2 miles and a thickness of about 30 feet, the quantity of coal available would amount to 792,000 tons for every 100 feet of inclined depth. Supposing the annual consumption to be 10,000 tons, the quantity would be enough to supply the required fuel for the next 79 years. But there being in all probability more than one seam, it may fairly be supposed that the quantity of coal in the Lashio coal-field is large enough to meet demands for fuel for the next 150 years should the railway be dependent on the Lashio coal-field alone for its supplies of fuel.

SECTION V.—THE MANZE-NAMMA COAL-FIELD.

Long. 97° 45′ and Lat. 22° 20′.

Situation of the coal-field.—The Manze-Namma coal-field is chiefly situated in the valley of the Nampong and one of its tributaries, the Namma.

2. ***Topographical features of the coal-field.***—To the south of the hills which border the Lashio valley from the south, there extends a vast region of low rolling hills, in the shape of a triangle, which is bordered by ranges rising to about 3,000 feet in the south-east and the lesser portion of the northern side, the bigger portion of the northern side being low hills, of about 1,300 feet in height. It is evident that this land forms a down-thrown region similar to that of the Gôkteik-Kunlôn valley. The chief drainage of this area is the Namma, which, running in a western direction, eventually joins the Namyaw. The Namma is formed by the junction of two smaller streams; the one coming from the north-east is called Nampong, the second coming from the east is called Nampyen; both join a little below the village of Namma, and from there the river is called Namma. It is along the banks of the two last-named streams that the outcrops of coal-seams may be seen.

3. *Geology and stratigraphy.*—The older strata are the same as those of the Lashio field, and nothing more need be said about them. The tertiary strata may be seen best along the banks of the Nampong between Manzè and Namma, and although the result was not very satisfactory as regards the coal-seams, it yielded very valuable observations about the tertiary strata. They consisted chiefly of grey and yellow sandstones, blue shales very finely bedded, like those met with in the Chindwin, and the concretions of hydroxide iron were not wanting. The strata have a general dip to east-north-east for about half the distance between Manzè and Namma, then the dip suddenly changes to the opposite direction. The tertiary strata therefore form an anticlinal fold. This observation is ample proof that the coal-seams found in this part cannot be deposited locally, and if we are justified in drawing conclusions regarding the Lashio coal-field from this condition of stratification, it may be held that the Lashio coal-field also is by nature a thrown-down block.

4. *Localities of outcrop.*—(1) The first outcrop may be seen on the left bank of the Nampong, a little above the village of Manzè. A thin coal-seam of about 4 inches in thickness may be seen here in the water-level; nothing of the surrounding strata is however visible.

(2) The second outcrop is a little below the same village, and here a little more can be seen. The lower stratum is formed by a thickish bedded sandstone of yellow colour on which rests a seam of 3 inches in thickness; then follows clayey shale, about 5 feet thick; then again a coal-seam of 6 inches, covered with the same clay; then follows river clay covering unconformably the tertiary strata. Dip, towards east-north-east, at an angle of 15°.

The results of the analyses of a sample of each seam are as follow:—

	Six-inch seam.	Three-inch seam
Volatile matter, including moisture .	53·60	55·42
Fixed carbon	34·22	34·94
Ash	12·18	9·64
	100·00	100·00

(3) The best outcrops are seen in the bed of the Nampyen near the village of Namma. It is not quite correct to say the "best" outcrops, because as regards the surrounding strata even less is seen of them than anywhere else; but there are unmistakeable signs that within the short distance of hardly a mile there are at least ten different coal-seams; and, if a conclusion as to the thickness of the seams may be drawn from the thickness of the lumps lying in the bed of the stream, none of them is less than 5 feet in thickness. The coal is of excellent quality, very hard, and of bright colour; and it can stand a considerable amount of wear and tear, as is proved by the fact that big lumps of fresh coal are rolled down stream amongst the big boulders of quartzite and porphyry without being smashed. However, the coal does not stand long exposure to water and air, as under their influence the laminæ of which the coal is composed become separated, and, together with the cleavage, the coal crumbles into small prismatic pieces. Dip, towards west-south-west at an angle of about 20°.

The following are the results of the analyses of five samples of the five biggest seams of the Nampyen stream :—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Volatile matter, including moisture	56·82	52·59	60·45	58·37	56·08
Fixed carbon	38·58	37·64	36·15	33·47	34·08
Ash	4·60	9·77	3·40	8·16	9·84
	100·00	100·00	100·00	100·00	100·00

Although this coal is a bituminous coal, which should properly be called lignite or brown coal, it will certainly make an excellent fuel. I estimate the aggregate thickness of the seams to be about 50 feet.

5. *Alluvial deposits.*—The causes which render the examination of the Lashio coal-field so difficult, namely the coat of alluvial deposits hiding the tertiary strata, are found to a higher degree in the Manzè-Namma coal-fields. The alluvial deposits consist here of a conglomerate which near Namma rests unconformably on the coal-bearing strata. The conglomerate consists chiefly of rounded boulders of white quartzites and porphyries, and is very similar in appearance to that of the Mainglon valley. Near Namma the alluvial deposits reach the considerable thickness of about 200 feet, and they can easily be traced for a long distance, as they form a most distinct escarpment lining the slope of the hills to the east.

6. *Extension of the Manzè-Namma coal-field.*—It is nearly impossible to give a fair estimate of the extension of this coal-field, as the map of this part of the country is not reliable, and distances cannot, therefore, be measured. It can however be said that this coal-field has a larger extension than the Lashio field, as I received information afterwards that coal-seams are rather numerous farther down the Namma stream. It is, however, impossible to say for the present what breadth the coal-field has. Its length will certainly be not less than about 20 miles. The most favourable part of it is near the village of Namma, but it is possible that an equally good part may be found farther down the Namma stream.

SECTION VI.—ECONOMICAL VALUE OF THE COAL-FIELDS.

Having discussed in the preceding sections the geological conditions and situation of the coal-fields it only remains to deal with the question as to whether these coal-fields in their present condition will be of any value. This question must be answered in the negative. The wealth stored up in these coal-fields will not be of any value so long as there is no communication by which it can be easily brought down to the Irrawaddi. The coal-fields are about 170 miles away from the next centre of traffic. The present road leading to them is only suited for carts for about 50 miles, after which pack animals must be employed. It need hardly be said that under these circumstances a profitable exploitation of the coal-seams is impossible. But even supposing that a road were made which would be practicable for carts all the year round, the coal-field could not be worked with profit. Coal that had to be transported by carts for about 170 miles would reach its destination, not only in very poor condition, but its selling price would be so increased by the cost of freight that it could not possibly compete with any other coal in the market.

It may therefore be said that as long as no other communication than the present one exists between the coal-fields and the plain of the Irrawaddi, the coal-fields are of no value whatever, and will remain a dead treasure.

The exploitation of the coal-fields will only be remunerative when the cost of transport has been so much reduced that the coal from them can fairly compete with other coal, and the collieries will also need a local consumer on which to depend. Both these conditions would be fulfilled by a railway.

Now, the proposed railway line will cut right through the centre of the Lashio coal-field, and will pass the Namma coal-field so closely that a branch line could be constructed to it without much additional cost. The railway could therefore depend for its supply of fuel on the two coal-fields, and not on one of them, and this favourable circumstance would guarantee a sufficient supply of coal in the event of one or the other of the coal-fields not answering expectations.

It therefore remains to examine the conditions which have first to be considered before any mining operations can be started. The Lashio coal-field has certainly the advantage of thicker coal-seams, but it is still doubtful whether the coal is equal in quality to that of the Namma coal. It may be, but, as the case stands now, the Lashio coal is certainly inferior in quality to the Namma coal. As regards extension, the Namma coal-field is undoubtedly the larger one. It is, moreover, doubtful whether the Lashio coal-seams may be depended upon to any length, or whether they are not so broken and disturbed in bedding that mining operations could not be carried on profitably. This does not apply to the Namma coal-field, or at least to that part of it which is exposed near the village of Namma. Here regularity of bedding has been observed which would guarantee a certain extension of the seams.

The alluvial deposits in both the coal-fields would form a serious obstacle to mining operations; while the thick layer of clay in the Lashio field and the conglomerate in the Namma field would make the sinking of a shaft difficult. Again, owing to the peculiar way in which the coal-bearing strata are found a large quantity of water must be expected in both coal-fields. Finally, the climate of these valleys is feverish, and the health of the miners would therefore be severely tried.

Note *on the* reported Namsèka Ruby-mine *in the* Mainglôn State, *by* FRITZ NOETLING, PH.D., *Palæontologist, Geological Survey of India.*

1. *Situation of the mine.*—Correctly speaking, the working which I am going to describe ought to be called the Namsèka Ruby-mine, because, from the name "Ruby-mines of Mainglôn" hitherto used, one might be led to believe that these mines are close to the town of the same name. However, nothing could be more erroneous than such a supposition, as there are no rubies within a considerable distance around Mainglôn. The mine is situated about 15 miles to the south-west of Mainglôn in the narrow valley of the Nampai, also known in its lower course as the Maddaya river. The exact locality where rubies are said to have been obtained lies about half a mile to the north-west of a small village called Namsèka, close to the junction of a small stream (called Namsèka) with the Nampai on the left bank of

the former. Its geographical position, according to the fifth edition of the preliminary map of Upper Burma, will therefore be Long. 96° 44′, Lat. 22° 46′.

2. *Geology.*—The greater part of the strata developed in the northern and western part of the Mainglôn State belongs to the gneissic and sub-metamorphic formations, as the latter is called in the Manual of the Geology of India; and the smaller part consists of recent river deposits of the alluvial system. No other formations have been found in that part of the country, the azoic rocks forming the hills, while the alluvial deposits fill up the valleys in different grades of extension.

(*a*) *The gneissic formation.*—The gneissic formation is as regards the country between Mainglôn and Mogôk, developed to the north of the Nampai, but in its western continuation it forms the hills on both sides of the Nampai. As regards the mineralogical character it may be said that the gneiss shows a Himalayan character, being of white or greyish colour, the common felspars being orthoclaes and albite. The gneiss is well-bedded and dips about 50° towards north. It seems to be traversed by eruptive granite, as, on the road between Mainglôn and Namsèka, large boulders of this rock can be observed for a short distance. Owing to the dense jungle, I could not, however, ascertain its exact relation to the surrounding gneiss, but it seemed to me that it was true intrusive granite.

(*b*) *Sub-metamorphic shales.*—The sub-metamorphic shales covered a larger area in the country which I examined than the gneissic formation. The hills to the south, east, and west of Mainglôn are formed by strata belonging to this group. The strata are represented by red and greenish shales frequently intersected by veins of milky quartz rock (? fault-rock). This group seemed to be much contorted, as the directions of dip changed frequently.

(*c*) *Alluvial deposits.*—The alluvial deposits consist of coarse and fine gravels, layers of big well-rolled boulders, and tough, brown gritty clay, which contains numerous angular grains of quartz rock. In the Namsèka mines these different constituents of river deposits do not change regularly; they are deposited without order and thus prove that they have been deposited by a torrent, and not by a large stream. The section of the strata in the pit gives a very good idea of this irregularity of bedding. At the farthest end of the pit, big boulders cemented by a coarse gritty clay are found, which are covered by a thick layer of fine brown clay. A little nearer the river a bed of coarse clay is noticed at the same level as the large boulders, which is covered by a layer of gravel; the clay frequently contains pockets of gravel and sand or big boulders. The strata thus clearly indicate the action of a torrent, which washed away at one place, say, the heavy boulders, while it deposited a pocket of sand; behind a protected corner the next heavy flood deposited large boulders again, which were covered by a layer of clay, and so on.

The pebbles and boulders chiefly consist of milky quartz-rock; gneiss or granite are scarce; there are occasionally some specimens of a black or blue silicious shale, but no traces of any limestone. The absence of limestone must particularly be noticed because the crystalline limestone is the original matrix of rubies.

These alluvial deposits are the ruby-bearing strata, but it is only in the sand or gravel that rubies are found, not in the clay. This proves clearly enough that the Namsèka rubies are not found in the original matrix, but that they, like the rest of the pebbles, sand, &c., have been transported by the water from some place higher up the river, and (have been like the rest) deposited by the river along its course at localities which were favourable for the deposit. Having ascertained the nature of the ruby-bearing strata; it was necessary to examine their extension, to find out whether they form a continuous bed along the banks of the river, or whether they were only deposited locally. This question was easily settled and it may be taken for granted that the river deposits do not form a continuous deposit, but that they are only found locally at places which were not only favourable for the deposit, but also protected the deposit once formed from being washed away again by the current. They therefore form mere pockets of no great extension which may be found anywhere along the bank of the Nampai or of the Mogôk stream. A description of the locality of the Namsèka ruby-mine will illustrate the nature of these pockets.

3. *Description of the locality.*—The Nampai, after having passed the broad valley of Mainglôn, has to cut its way through the gneissic rocks and the shales which form the hills west of the Mainglôn valley, making its way in a meandering course through the hills; its valley is frequently a narrow gorge through which the foaming waters flow with tremendous rapidity, while at other places, where the valley widens out a little, the river forms quiet pools, sometimes of considerable depth. Just before reaching the place where the ruby-bearing sands are now deposited, the Nampai comes down with tremendous speed from the north-east, but is checked in its course by a promontory on its northern bank, round which it has to make its way, taking then a northerly course. Just opposite to the promontory, on the left bank of the river, there was a small ravine, the outlines of which can still be traced. Along the slope of the hills it seemed to have had a very narrow outlet towards the river, while it widened out in its upper part. This ravine being well protected against the torrent coming from the east, nevertheless afforded an easy access to the water from the north, the bar at its end being low; particularly when at high flood the water was rushed against the promontory, and, being unable to find its way through a narrow passage, was forced into the ravine on the opposite bank; the ravine was thus gradually filled up by the detritus of the Nampai. Subsequent floods may have partly washed away the deposits which were most exposed, while others may again have increased their quantity, but the bulk was deposited safely in the hollow of the ravine.

I estimate the height up to which the ravine was filled to be about 50 to 60 feet above the level of the Nampai at low water.

4. *Description of the pit.*—The pit was about 400 feet in length, contracting at its northern end to a narrow passage just sufficient to afford passage for one man; it widened out to about 150 feet on the surface, but the bottom, where the men worked, hardly afforded room for two men to excavate the sand. The pit was therefore a funnel-shaped hole in which the workmen had to work under permanent danger of their lives, as the sides, not being supported by timber, might give way any moment, and fill up the whole pit.

(*f*) *Manner of washing for rubies.*—To facilitate the digging, the former workmen had constructed a small channel bringing the water to the top end of the pit where it was made to run down the walls, thus softening the hard clay. The workmen then put the sand or gravel into small baskets, which were brought down to the river, where they were put into flat baskets, and by a rocking movement in the water, the clay was first removed. If there were any stones of particular size they could then be noticed and picked out, the larger pebbles thrown away and the remainder carefully washed under a permanent rocking movement. If repeated two or three times, and no rubies were discovered, the whole sand in the basket, which by this time had been reduced to fragments of the size of a pea, was thrown aside.

(*g*) *My experiments.*—When I visited this pit it showed signs that it had not been worked for a long time. I therefore expected to get good results. My trials were repeated for three days, each day working for eight hours with 12 coolies. The coolies were carefully watched, not only while digging, but particularly during the operation of washing. I was therefore quite sure that any theft of stones was impossible. I proceeded in the same way as the natives were accustomed to do. The ruby-bearing sand, when brought out of the pit, was a dirty, clayey earth which made any mineral, even the pure white quartzite pebble, perfectly indiscernible; to pick out any ruby from this stuff in the short time within which it was brought from the pit to the river would, in my opinion, have been impossible. I even doubt whether the men working in the pit could have abstracted any stone provided it were not an exceptionally large one, so completely did the brown clay conceal the true nature of every pebble or stone. After the first washing there remained a gravel chiefly composed of white quartzite pebbles and a finer sand composed of various rocks and minerals. When the larger pebbles were removed and the finer sand was repeatedly washed, there was left a sand consisting chiefly of quartzite in various colours, those of milky colour prevailing, numerous spinels, a few crystals of hæmatite and occasionally a fragment of titanite or schorl (black tourmaline), but no rubies. It must particularly be mentioned that all these minerals were found in angular fragments, having sharp edges; hardly a single specimen was rolled. This is certainly a proof that they could not have been transported for a long way, or else they would have lost their angular shape.

I paid of course special attention to all "red" minerals, but they all proved to be spinels, not a single ruby being amongst them. The spinels were all of the same poor colour, dark purple, nearly black, and none of the fragments were of any size worth mentioning. The surface of the spinels had a peculiar appearance; it was honeycombed and the cells were filled with a yellow, soft mineral which I suppose to be hydroxide of iron, and which could be removed entirely by washing and brushing. This may be considered as the first sign of superficial disintegration. Specimens were not unfrequently met with, which had turned into hydroxide of iron, still preserving, however, their original shape.

(*h*) *Do the Namsèka ruby-mines contain rubies or not?*—The first samples of rubies which were sent by Lieutenant Daly, Superintendent, Northern Shan States, to the Government of Burma, and which were said to have come from the Mainglôn ruby-mines, were exceedingly fine specimens. They were not large, but of very good colour, some of them nearly flawless and nearly all well crystallized, or if fragments, showing at least a few crystal faces; the edges were all sharp, and not water-worn. A mine producing such stones was certainly very promising, and I was therefore much surprised that I did not find during these three days, with 12 coolies working 8 hours each, a single ruby, and not even a fragment. This was most surprising, as it might fairly be expected that the trials were sufficient to prove the existence of rubies if there were any. I therefore felt inclined to think that the Namsèka ruby-mines must have been either worked out, or that they never produced any rubies at all. As they were not exhausted, that is to say, as the total of the alluvial deposits had not been exploited, I could only accept the conclusion that they did not contain any rubies at all.

Strange to say this conclusion was supported by a most remarkable story about the origin of the rubies sent to the Government. When the Thibaw Sawbwa sent one of his officials to Namsèka to get samples of good stones from the mines, none could be procured. The man therefore went over to Mogôk, where he purchased the stones which were handed over to the Sawbwa as "Namsèka rubies." I give this story as it was told me, and I do not venture to use it in any way to support my views about the value of the Namsèka ruby-mines. I must, however, mention that it was told voluntarily to me, and that the informer did not know the view I held about the mines.

On my way back, passing Thibaw, I told the Sawbwa my doubts as to the Namsèka mines; but he produced a large tray of rubies, amongst which were some excellent stones of good colour which in their appearance perfectly agreed with the stones forwarded by Lieutenant Daly to the Government; and he assured me that all these stones came from the Namsèka mines. To do him justice, I must admit that the samples shown to me contained all sorts of stones, rubies of different colours and shapes, rolled and crystallized, numerous fragments of spinels, of the same appearance as the Namsèka spinels, and a number of minerals, such as are associated with rubies and spinels. Had these samples actually been bought at Mogôk the man who bought them would have shown a good deal of foresight by also buying minerals which, though valueless in themselves, are found together with rubies, so as to make the fraud a complete one. I must admit that with these reflections and in the face of the positive statements of the Sawbwa, I do not feel justified in giving a final decision about the value of the Namsèka ruby-mines without having examined them again, and for a longer time.

Several questions, however, first require answering, namely,—

(*a*) Were the ruby-mines which I visited and examined actually those from which the stones in the possession of the Sawbwa had been obtained? As to this there can be no doubt that I actually visited the place from which the rubies were stated to have come. The mine was fenced in, there was an old guard-house to prevent outsiders from digging, and there is no room for any other ruby-bearing deposit round Namsèka. Besides, the Sawbwa was most anxious to learn something about his valuable mining property, so that I do not see any reason why he should have deceived me by sending me to the wrong place. Furthermore, Mr. Hertz, who has stayed for several months at Mainglôn, has only heard of one ruby-mine near Namsèka; and he would certainly have heard if there had been more mines from which rubies had been extracted, along the bank of the Nampai, if such mines were in existence; because, as far as I know, the first information about the Mainglôn ruby-mines came through Mr. Hertz. Taking everything into consideration there can be no doubt as to the identity of the "Namsèka" ruby-mines.

(*b*) The question as to the locality having been answered in the affirmative the next question to be answered is—Are the rubies found in certain strata, or are they to be found irregularly distributed amongst the alluvial deposits described in paragraph 2(*c*)? If the rubies are confined only to a certain stratum or strata, then I must admit that either my operations did not touch such or else that they were completely exhausted by former diggings and had consequently disappeared. Now, from the nature of these deposits I doubt that regular beds existed, for the section as exhibited in the pit shows clearly that there is no regularity as regards bedding; the theory of a regular ruby-bearing bed must therefore be dismissed as not being in accordance with the nature of the deposits, and it is more likely that the rubies are distributed irregularly, like any other pebbles or minerals through the whole of the deposits. This may, however, be restricted in some way; there may have existed a pocket of sand or gravel which was particularly rich in rubies, and it may have been from this pocket that the Sawbwa's stones came. This pocket having been completely worked out, the other strata do not contain rubies at all or only in great scarcity. It seems to me that this theory about the occurrence of the rubies is the more probable one, but it can only be tested by a repeated and more extended examination.

5. *The origin of the rubies.*—However, supposing the rubies were actually found in the Namsèka; from the way in which they were found, there cannot be the slightest doubt but that they are not in their primary matrix. They form part of the river deposits, and have been transported by the river, like other stones, from some spot higher up, and they no more originate in the spot in which they are found than the ordinary river gravel. In paragraph 2, I particularly mentioned that no crystalline limestone, the original matrix of rubies, has been found yet. These two observations prove that the rubies cannot come from the immediate neighbourhood of Namsèka, although from their shape it may be concluded that the original matrix which yields the rubies cannot be very far away.

Now, fortunately there is absolute proof that the rubies cannot have been washed down by the Nampai. I examined the deposits of the Nampai around Mainglôn and did not find a ruby or spinel or even fragments of these stones. As they extend to about 10 miles east of Namsèka, the locality from which the rubies came must necessarily be situated between Namsèka and the western limit of the river gravels of Mainglôn. As there is, however, no crystalline limestone, we must suppose that they were brought down by a stream coming from the north. The only stream of importance is the Mogôk stream, which joins the Nampai about a quarter of a mile above the Namsèka ruby-mines, and it may therefore be supposed with a great degree of probability that any rubies found in the Namsèka mines have been washed down from the ruby-mines district by the Mogaung river.

6. *Probable extension of Ruby-bearing sands in the valley of the Nampai and Mogôk streams.*—Having in the previous paragraph pointed out the way in which the rubies said to have come from the Namsèka mines may have been transported, the question to be answered is whether there is any probability of any more ruby-producing localities being discovered along this way. This question may be answered in the affirmative, and it may be stated that there is the greatest probability of discovering such deposits along the bank of the Mogôk stream, but that the chances get fewer by going farther down the Nampai, provided there is no other feeder from the ruby-bearing strata of the Ruby Mines district. From the nature of the deposits in which rubies are found it may, however, be concluded that they nowhere cover a large area; at suitable places, in small ravines or behind a hill projecting into the river, they may be looked for and met with, but these pockets would soon be exhausted; and I therefore doubt whether it would pay a European company to work these deposits the real value of which has, moreover, not been ascertained.

The following is a summary of the facts which have so far been obtained as regards the occurrence of ruby-bearing deposits in the valley of the Nampai, generally known as the Mainglôn ruby-mines:—

(*a*) the rubies are not found in their primary matrix;

(*b*) the rubies are found in secondary deposits namely river gravel and sand; they have therefore been removed by the action of the water from the place when they originally existed;

(*c*) the river deposits (gravel and sand) do not form a continuous layer along the banks of the river;

(*d*) they are found at isolated places, which were suitable for their deposit and preservation, thus forming pockets of very limited horizontal extension, and also hardly reaching higher up than 50 or 60 feet above the low water-level;

(*e*) there is, however, every probability that along the banks of the Mogôk stream and Nampai more such pockets as the Namsèka ruby-mine may be discovered; the chances, however, get less with increasing distance from the place where the Mogôk stream joins the Nampai;

(*f*) unless a large number of such pockets are discovered, it would not pay systematic exploitation, even should rubies be found;

(*g*) it is still doubtful whether the Namsèka ruby-mine ever produced rubies, or whether it will produce them in the future.

Note *on the* Tourmaline (Schorl) Mines in the Mainglôn State; *by* FRITZ NOETLING, PH.D., *Palæontologist, Geological Survey of India.*

1. *Situation of the mines.*—The mines are situated in the broad valley which extends north of the town of Mainglôn, from north-east to south-west for a distance of about 5 miles with a maximum breadth of nearly 2 miles. The geographical position may be Long. 96° 41′, Lat. 22° 46′. The valley is traversed by the Nampai, which, coming from the hills to the north-east, slowly makes its way through the broad plain until it disappears again as a wild torrent in the narrow gorge which forms the western outlet of the valley. The mines are situated on both sides of the Nampai along the slopes. The principal mines are near the villages of Naungdaw and Naungheng, about 2 to 3 miles to the north of the town of Mainglôn. No mines are near this place itself.

2. *Geology*: (*a*) *Gneissic and submetamorphic formations.*—As regards the azoic formations they are the same as those observed in the neighbourhood of Namsèka, and everything that I have said about these formations in my report on the Namsèka ruby-mines also applies to them as far as the country around Mainglôn is concerned. The gneiss is particularly developed north and north-east of the Nampai, while the submetamorphic shales are found in the south and the west. Mainglôn itself is situated on a low hill projecting to the north, which is formed by green shales, dipping towards the west, covered by a thick layer of river conglomerate of about 50 feet in thickness.

(*b*) *Alluvial deposits.*—Amongst the alluvial deposits found in the Nampai valley we can distinguish two groups: (i) an older one consisting of conglomerates and red clay, and (ii) a younger one consisting chiefly of black tough paddy-soil. While the first group is found up to heights of about 200 feet above the present level of the river, the second one is strictly limited to the low plains.

(*b*) (i) *The older river deposits. I. Conglomerates.*—The conglomerates which form, so far as is known at present, the basis of the older alluvial deposits consist chiefly of well-rounded smooth pebbles of quartz-rock in various sizes, from small grains up to the size of a man's head and over. Other rocks are scarce, and only occasionally a small pebble of blue silicious shale, or rotten schistose sandstone is found; not uncommon are well-rounded pebbles of black tourmaline (schorl) reaching the size of a walnut. These have sometimes their original crystal shape preserved still, but they always show that they were much water-worn; much scarcer evidently is the red tourmaline, as I did not succeed either in discovering a specimen *in situ* or in obtaining samples of it from the natives. The only sample I have seen I received through Lieutenant Daly; it was a small fragment of a crystal of pale pink colour stained with flaws and much rolled. The natives stated that occasionally big specimens are found which are sold at a high price, but they are very scarce. They even say that small specimens of hardly any value are not common. Besides the minerals mentioned, I found a fragment of rock crystal and a piece of agate. The monotonous composition of this conglomerate proves clearly enough that it is made up from the débris of a country where there was only a small variety of strata; very likely the strata consisted chiefly of gneissic and granitic rocks. The pebbles are cemented by a coarse gritty clay of yellowish colour, thus forming a compact hard mass, which is hardly affected by ordinary tools, as the pickaxe rebounds on the smooth rounded quartz-rock pebbles.

It is very likely that the conglomerate, like all other strata of similar composition, contains a smalt quantity of gold which was extracted by the miners. I do not say that gold-washing operations were their chief object, but I feel strongly inclined to think that they gave the original start and that in the progress of the work the tourmalines were discovered and the exploitation of these stones, highly valuable in the eyes of Chinamen, was gradually substituted for that of gold, although the latter was never quite neglected. I did not, however, succeed in getting information on this point, as the natives were very suspicious lest anything should be known.

II. The red clay.—The conglomerates are everywhere covered by a layer of tough red clay, not particularly gritty, but containing numerous angular grains of quartz-rock and felspar. The clay does not show any sign of bedding, and forms one continuous layer from the floor to the top. Its thickness varies much, as at some places it certainly exceeds 50 feet, while at others it is between 15 and 20 feet. It is most remarkable that clay and conglomerate never alternate, but that they are separated by a sharp limit, the clay being always on the top of the conglomerate, which it conceals perfectly. The soft, rounded features of the low hills round Mainglôn are due to this superficial coat of red clay.

(*b*) (ii) *The younger river deposits.*—There is not much to be said from a geological point of view about these deposits, although they certainly form a most valuable tract from an agricultural point of view. There is the well-known dark grey or black soil, a tough clay mixed with a high percentage of decomposed organic matter, which would afford excellent paddy ground if irrigated. The younger river deposits are strictly limited to the lowlands in the Mainglôn valley.

3. *Extension and origin of the older alluvial deposits.*—In a continuous layer the older alluvial deposits are especially found along the slopes of the hills which border the Mainglôn valley. They, however, also form isolated hills or short ranges in the centre of the valley, thus proving that they originally filled the whole valley, but became afterwards divided, probably by the action of the Nampai, which cut its bed through these deposits, only leaving them along slopes of the hills, and here and there in isolated patches in the centre of the basin. Along the slope of the hills they form a very distinct escarpment level at its surface, being in accord with that of the hills in the centre of the valley. The deposit of two strata requiring conditions so absolutely different in one and the same locality, and evidently immediately succeeding one another, forms, however, a problem which cannot easily be solved. The compact mass of the conglomerate must have been deposited under the influence of a very strong current, while the clay must naturally have been deposited in still water. That conglomerate and clay cannot have been deposited in or by one and the same water is proved by the sharp separation. If they were deposited gradually, there must certainly be found some kind of intermediate bed, from coarse gravel gradually leading to fine sand and clay, but nothing of this kind is observed, and the clay rests immediately on the top of the biggest pebbles. I believe that the Mainglôn valley formed a kind of lake on the bottom of which the Nampai deposited the bulk and particularly the heavier parts of the débris, thus forming the conglomerate, while the silt and finer material were carried away. Gradually the basin of the lake became more and more filled up, and consequently the level of the water rose. Now, there must have been a day when the bar which closed the western outlet of the lake gave way, and the water digging its way through its own deposits and carrying large quantities of them away, thus formed the channel through which now the Nampai runs, and through which the heavier material was transported in the future. Occasional high floods may have sometimes restored the old lake when the outlet was still narrow and was blocked, but the heavier material was no longer stored up, and the current was always strong enough to carry it away through the channels which formed in the dry season the river bed. Along the borders of the lake and wherever there was quiet water the finer material was deposited on the top of the older conglomerate, thus forming the younger clay.

I did not find any organic remains in either conglomerates or clay. That none could be preserved in the conglomerate is intelligible, but it is rather strange that no shells should have been preserved in the clay. However, they may be discovered hereafter.

4. *Description of the mines.*—The pits, now deserted, from which the tourmalines were dug are numerous, and those which have apparently been worked quite recently may be seen anywhere along the slopes of the valley. The place for making a pit was always chosen with a view to getting an easy and ample supply of water for washing purposes, and was so situated that the finer débris and used water could easily be got rid of. The pits are therefore all at a certain height above the present river level, while the water is brought down from higher places in channels of considerable length. It is therefore easily understood that for these two reasons the workmen can only exploit the conglomerate at a certain limited height. If the pits are too high up on the slope, it is rather difficult to get a sufficient supply of

water; if too low down, the water will not easily flow off. The style of work is simple enough. At first the covering clay is removed till the surface of the conglomerate is exposed. As a rule, a large piece of conglomerate is freed at once. In the pit the surface of the conglomerate measured about 250 by 105 feet. As the thickness of the clay averaged about 10 feet, the quantity of clay to be removed before the operations could be started was very considerable.

The water, in a channel coming from the south-east, was conducted in the back ground of the pit along the perpendicular wall of clay, to the place where it was wanted for working purposes. It was then made to run on the surface of the conglomerate and to trickle down in part of the working place, thus softening the clayey cement, so that the pebbles could afterwards be easily removed. The miner, by heaping the larger pebbles on the free room behind himself, while searching the conglomerate in front, gradually turned over the whole of the conglomerate without being obliged to carry away the large and heavy pebbles. The smaller débris was washed in baskets, the tourmalines picked out, and the remainder probably re-washed for gold. The conglomerate has been nearly completely worked out at the southern side of the pit. A few rests are still remaining as a support to the water channel. On the northern side there is still a large quantity left, but when this is worked out, either the pit will have to be deserted or the tiresome work of removing a still larger quantity of clay than in the beginning will have to be started again.

It is perfectly clear that this kind of work requires large quantities of water. The mines can therefore only be worked during the rainy season and for a short time after its termination. It is intelligible that the difficulties are therefore such as to make tourmaline mining not only a slow but also a not very profitable business, if the scarcity and the comparatively small value of the mineral be taken into consideration.

5. Old mines.—Tourmaline being a mineral which is generally associated with granite, I was of course anxious to trace, if possible, the original locality whence the specimens found in the conglomerate were derived. As all the signs pointed to the north-east as this probable source, I extended my examinations up the banks of a small river called Nyaungdauk, where at a place called Mawtunim, large deserted pits could be seen. It was stated that the Chinese had formerly worked these pits. When I visited this locality I saw a large circular pit of about 300 feet in diameter and from 100 to 150 feet deep on the slope of the hill; the walls and the bottom were, however, covered with dense jungle; on the outer side of the dry pit there were numerous smaller ones, and large heaps of refuse proved too clearly that once extensive mining operations had been going on here. I was, however, unable to find out with certainty the object of these mining operations, although I searched the refuse for a long time. The refuse consisted of pieces of granite, and, although I carefully looked for, I did not find even the slightest trace of, a metallic ore. If such had been the object, traces of it would certainly have been found. Amongst the refuse I discovered, however, numerous crystals of black tourmaline (schorl). As the hill was formed of granite, it is very probable that at this place a vein yielding pink tourmaline was exploited, and that the rolled specimens of this mineral must originate somewhere in the neighbourhood of this place. It would, however, require extensive clearings to ascertain the correctness of this opinion, and I should not recommend them, considering the small value of tourmaline. A similar pit of larger size was said to exist about 2 miles higher up the stream.

Note *on a* Salt spring *near* Bawgyo, Thibaw State, *by* FRITZ NOETLING, PH.D., *Palæontologist, Geological Survey of India.*

Situation of the Salt spring.—It is a rule that great faults are usually accompanied by springs following the line of disturbance. The great fault which begins near the Gôkteik pass and extends probably far beyond the Salween, is no exception to this rule. Its way is marked by several springs, the water of which is more or less alkaline, and the temperature of which reaches the boiling-point in some cases. It is of course only the salt springs that are of special economical value, as under skilful management they might prove an exceedingly profitable source of revenue. For the present, only one salt spring is known, from which salt is produced by the ordinary method of evaporating the brine in cauldrons. This salt spring is situated about half a mile to the west of the village of Bawgyo in the Thibaw State; its geographical position is about 97° 15′ East and Long. 22° 35′ North Lat. A regular well has been dug by the villagers, which is well lined with timber, and from which the brine is drawn. I have been told that there was formerly a second well, which, however, yielded so large a quantity of brine that the villagers were unable to work it, and therefore filled it up again.

2. *Analysis of the brine.*—The analysis of a sample of the brine taken by me and sent to Rangoon proved that one gallon contains 8,771 grains of solid residue, or 12·53 per cent. I do not think, however, that this represents the average percentage of solid matter contained in the brine. The villagers stated that during the rainy season one of the cauldrons produced 2½ viss per day. During the hot season the same quantity of water produced 4 viss of salt per day. The reason of this difference is easily intelligible. During the rainy season a considerable quantity of the rain water falls into the well, thus diluting the brine, the diluted portion of which, being of course of lower specific gravity, floats on the top and is therefore extracted. During the hot season no such dilution takes place, hence the difference in the output. I took the sample on the 8th June, that is, at a time of the year when it had already rained heavily, so that the brine was already a little diluted.

Supposing the amount of solid matter to be correct, the brine would contain 5,288 grains of sodium chloride (common salt), 3,038 grains of sodium sulphate, 87 grains of calcium sulphate, and 75 grains of magnesium sulphate, to the gallon, the rest being moisture, organic matter, &c., according to the following analysis:—

	Per cent.
Sodium chloride	60·30
Sodium sulphate	34·64
Calcium sulphate	1·00
Magnesium sulphate	0·86
Undetermined (moisture, organic matter, &c.)	3·30
TOTAL	100·10

Unfortunately I have only the analysis of the brine of Sadwingyi for making a comparison. Mr. Blanford states that this salt spring is one of the most productive known in Pegu. It contained 4,704 grains of salt to the gallon. Mr. Blanford does not say whether under the word "salt" he understands the total of solid matter, *i.e.* sodium chloride, sodium sulphate, &c., or whether he means only the amount of sodium chloride. Supposing the word "salt" means the amount of sodium chloride, the Bawgyo brine would contain a considerably larger quantity of salt than the richest brine known up to the present time in Burma. If, however, the amount represents the total of solid matter, the Bawgyo brine contains nearly double the quantity. At any rate we may consider the Bawgyo brine to be the richest now known in Burma.

3. *Analysis of salt as produced by the natives from the brine and sold in the bazaar.*—The first matter of importance which the natives everywhere told me about the Bawgyo salt was, that it could not be used for food, as it had a peculiar bitter taste; consequently, it could hardly be sold in the bazaar, and 20 viss only fetched 4 annas, while the price of best imported salt was 6 annas per viss. When tasting the salt I did not notice the bitter taste particularly, but from the mode of manufacturing the salt, by evaporating the brine till nothing but the solid matter was left, it was perfectly clear that all salts, which were contained in the brine and which have a particularly unpalatable taste, such as sodium sulphate, were contained in the "salt," and hence its peculiar bitter taste. The analysis of a sample of salt confirmed my idea. The salt as sold in the bazaar had the following composition:—

	Per cent.
Sodium chloride	50·14
Sodium sulphate	42·33
Calcium sulphate	0·63
Magnesium sulphate, a trace	...
Undetermined (moisture, &c.)	6·90
TOTAL	100·00

4. *Manufacture of the salt.*—The manufacture of salt is simple enough. Every fifth day the brine is drawn from the well and filled into large wooden troughs coarsely cut out from a log; from there the brine is filled into flat cauldrons and boiled down till all the water is evaporated. The salt is then taken out, and is ready for sale. Under an ordinary bamboo shed there are about 14 wooden troughs to take up the brine and salt, arranged in a square, the centre of which is occupied by three furnaces, each containing two cauldrons. The furnace is not constructed in any particular way; its length is about 6 feet, its height about 1 foot 6 inches, and it is of oblong shape. The front opening at one of the small sides serves for the supply of firewood, while the back opening on the opposite side serves as an outlet for the smoke. At the top of the furnace are two flat cauldrons, each of about 2½ to 3 feet in diameter; on one side of each cauldron there are two low baskets to receive the salt which is skimmed from the surface of the brine. The natives state that such a furnace does not last longer than two months; at the end of that period it is broken up, and the clay pounded and mixed with brine to extract the salt which collected in it during the boiling process. The total number of cauldrons is said to be 30.

5. *Production and working expenses.*—It was extremely difficult to get any reliable information about the production, as either the natives really did not know the exact amount produced every month, or, what seems to me more likely, did not

want to give me exact information for fear of being taxed. It was stated that the daily production is about five cauldrons, each yielding 2½ viss of salt during the rainy season and 4 viss during the dry season. The daily production would thus range from 12½ to 20 viss. Supposing that during six months the brine yields the large, and during six months the smaller quantity, the present total annual production would amount to 5,850 viss. Of this quantity half goes to the Sawbwa as royalty and half to the villagers as reward for their labour. The salt being sold at R2-8 per 100 viss, the total gross value amounts to R146-8. As the villagers, however, stated that the working expenses, particularly for firewood, amounted to R2 per 100 viss, the actual surplus would amount to the paltry sum of R29-8 per annum, half of which goes to the Sawbwa. Should these statements be correct, it is clear why the villagers do not like the work, as it does not pay enough in their opinion.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 7.—Ending 30th April 1891.

Director's Office, Calcutta, 30th April 1891.

The staff of the Survey remains disposed in the following parties :—

Madras Party.—R. B. Foote, F.G.S., Senior Superintendent, Cuddapah District.

Burma Party.—Theo. W. Hughes Hughes, A.R.S.M., Superintendent, Tenasserim.
Fritz Noetling, PH.D., Palæontologist, Upper Burma.
H. Warth, PH.D., Tenasserim.

Punjab Party.—C. L. Griesbach, C.I.E., Superintendent.
C. S. Middlemiss, B.A., 2nd Grade Deputy Superintendent.

Baluchistan Party.—R. D. Oldham, A.R.S.M., 1st Grade Deputy Superintendent.
Sub-Assistant Hira Lal.
Sub-Assistant Kishen Singh.

Darjeeling and Sikkim.—P. N. Bose, B.SC., 2nd Grade Deputy Superintendent.

Bengal Coal-Fields.—T. D. La Touche, B.A., 2nd Grade Deputy Superintendent.

Assam.—P. N. Datta, B.Sc., Assistant Superintendent.

Head-Quarters, Calcutta.—The Director; T. H. Holland, A.R.C.S., F.G.S., Assistant Superintendent, Museum and Laboratory.

The field season being over for most of these parties: Messrs. Oldham, La Touche, and Sub-Assistants Hira Lal and Kishen Singh are returning to head-quarters. Mr. P. N. Datta, having broken down through sickness, will also return to head-quarters.

Dr. Noetling remains in Upper Burma, being closely associated with the Financial Commissioner's office at Rangoon in connection with the settlement of the demarcation and leasing of the Yenangyoung and Minbu oil-fields. He is also engaged on exploration duty at the possible occurrence of coal in the Myingyan district. We do not entertain any hopeful expectation of coal being met with on that side of the Irrawaddi valley; but it is necessary to set the point at rest, in view of the proposed construction of a railway branch in that direction.

Mr. Middlemiss is on deputation with the Black Mountain Expedition.

Mr. Griesbach availed himself of privilege leave for three months on the 9th April.

The Director was on tour in Lower and Upper Burma from the 12th of March to the 29th of April, when, besides other work, the tin exploration in Tenasserim and the coal and oil exploration in Upper Burma were inspected. The results of the tin exploration are very promising at Maliwun, Thabawleik, and on the Little Tenasserim river; so much so that there is every reason for concluding that the ultimate development of these tracts under a system of encouraged Chinese labour, similar to that of Perak, will prove a fruitful source of revenue in the Mergui district. A most important find in the neighbourhood of Maliwun is that of a stanniferous zone of rocks—which, for practical purposes, may be called a 'reef'—which is evidently one of the sources of the tin-bearing gravels in that region. The legitimate inference arising out of this discovery is that, as the pathless and dense jungle becomes cleared in places from the hills confining the alluvial tracts, very many more such stanniferous zones shall be found, possibly of sufficient richness to offer inducement even for the starting of European mining when the country shall have become more opened out and populous.

The Yenangyoung and Minbu oil-fields were next visited, when it was most satisfactory to find that the structure of the former field has been thoroughly and successfully studied by Dr. Noetling, while his demarcation of the area into convenient blocks has been judiciously aligned with a persistent anticlinal, the crest of which is the gathering or collecting zone of oil assemblage on that side of the Irrawaddi river.

So far, this oil development is progressing very favourably; the production is on the increase, while the supply of oil remains undiminished. There is likewise every prospect of the oil-bearing zone, having a productive extension for many miles to the northward of the present area, because the anticlinal, though much squeezed and even broken in many places, preserves a persistent strike to the northward for over 160 miles, as far as Mingin on the Chindwin river. As it is, there is the oil-field of Yanangyat, which is also being demarcated, and further oil indications, north-west of Pokoku and south-east of Kongma, on the same line.

The Minbu field below Yenangyoung, but on the right bank of the river, is also being demarcated. It lies on a parallel anticlinal, the northerly and southerly extensions of which have yet to be tracked out.

List of Reports and Papers sent in to Office for publication or record during February, March, and April 1891.

Author.	Subject.	Disposal.
R. D. OLDHAM	Report on the outflow of petroleum in the Robdar valley, Bolan pass.	To be printed for loca Government.
"	Report on the petroleum resources of the country adjoining the routes to Quetta.	
T. D. LA TOUCHE . .	Note on the geology of the Lushai Hills.	Appear in the current Records, Geological Survey of India.
T. H. HOLLAND . . .	Mineral oil from the Suleiman Hills (Moghal Kot): and appendix.	
Dr. FRITZ NOETLING . .	Report on the coal-fields of the Northern Shan States.	
" . .	Note on the reported Namsèka Ruby-mines in the Mainglon State.	
" . .	Note on the Tourmaline mines in the Mainglon State.	
" . .	Note on the Salt spring near Bawgyo, Thibaw State.	
P. N. DATTA . . .	Coal research on the North-West Frontier of the Garo Hills.	Record.
F. R. MALLET . . .	Translation of a portion (Ceylon and Salem) of M. Al. Lacroix' *Contributions dé l'étude des gneiss à pyroxène et des roches à wernerite.*	Will appear in the Records, Geological Survey of India, for August next.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of February, March, and April 1891.

Substance.	For whom.	Result.
Quartz, for gold . .	G. APCAR, Calcutta.	
3 specimens of felsite, quartzite, and blue quartz, for gold.	W. P. STEPHENSON, Calcutta.	
Granulite with garnets, for opinion.	W. H. P. DRIVER, Ranchi.	
Pistacite vein in decomposed granite, magnetite, chalcopyrite and quartz, for opinion.	R. C. MCKENNIE Calcutta.	
Quartz, quartz with plates of specular iron-ore, and quartzite.	J. MUNRO, Chandil.	
3 specimens of quartz, for gold, and a specimen of specular iron-ore. for iron, from the Porahat jungles.	J. M. STONEY, Calcutta.	
3 specimens of coal, taken from the borings in Hilogoria, for assay.	KILBURN & CO., Calcutta.	
Specimens of earth and carbonaceous powder, with crystals of selenite, from between the Roshalin and the Gugger rivers, for opinion.	W. COLDSTREAM, Deputy Commissioner, Simla district.	

<table>
<tr><td>2 specimens of quartz, for gold, and a specimen of micaceous iron-ore, for iron, from the Porahat jungles.</td><td>J. M. Stoney, Calcutta.</td><td colspan="4"></td></tr>
<tr><td rowspan="3">4 specimens of tin-stone from Kumong, Maliwún, for assay.</td><td rowspan="3">T. W. H. Hughes, Geological Survey of India.</td><td>A.
From Hill No. 2, North-West Kumong, Maliwún.
Quantity received, 14·24 oz.</td><td>B.
From Hill No. 1, west of Camp Kumong, Maliwún.
Quantity received, 1 lb 9·20 oz.</td><td>C.
From another part of Hill No. 1, west of Camp Kumong, Maliwún.
Quantity received, 9·14 oz.</td><td>D.
From Tailings No. 1 of Sample (A).
Quantity received, 3·90 oz.</td></tr>
<tr><td>Yielded on assay :—
43·89 °/₀ of tin (Sn.)
Contains large quantities of iron, manganese, and tungsten, derived from the wolfram mixed with the cassiterite.</td><td>69·66 % of tin (Sn.)
Contains iron, manganese, and tungsten in small quantities only. The best sample of thefour.</td><td>36·56 °/₀ of tin (Sn.)
Contains iron pyrites, mica, quartz, felspar and wolfram mixed with the cassiterite.</td><td>44·80 °/₀ of tin (Sn.)
Contains large quantities of iron, manganese, and tungsten, derived from the wolfram mixed with the cassiterite.</td></tr>
<tr><td colspan="4">All the specimens contain lime in small quantities.</td></tr>
<tr><td>Coal taken from surface beds and sides of the upper reaches of the Doigrung river, in the Mikir and Rengma Hills, Naga Hills district.</td><td>Jas. Rollo, Executive Engineer, Naga Hills division.</td><td colspan="4">Two average samples selected from the quantity received (3 maunds), gave the following result :—
(1) / (2)
Moisture . . . . 9·88 / 9·10
Volatile matter . . . . 54·36 / 56·84
Fixed carbon . . . . 23·46 / 22·96
Ash . . . . 12·30 / 11·10
100·00 / 100·00
Does not cake, but sinters slightly.
Ash—light buff.
Contains a good deal of mineral resin.</td></tr>
<tr><td>Tin-ore, from Maliwún, for assay.</td><td>Dr. H. Warth, Geological Survey of India.</td><td colspan="4">Contains, besides cassiterite, a few black grains of wolfram, minute quartz granules, and a few grains of spinel. Yielded on assay :—
73·52 per cent. of tin (Sn.)</td></tr>
</table>

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of February, March, and April 1891—continued.

Substance.	For whom.	Result.
2 specimens of coal, from the Garo Hills, for assay.	P. N. DATTA, Geological Survey of India.	Rongap river outcrop, Rongraigin basin. Quantity received, 10 oz. / Rongren Jhora outcrop, Rongraigin basin. Quantity received, 19 oz. Moisture . . . 8·84 / 10·70 Volatile matter . . . 44·10 / 39·98 Fixed carbon . . . 29·86 / 37·08 Ash . . . 17·20 / 12·24 100·00 / 100·00 Sp. gr. . . . 1·22 / 1·28 Does not cake, but sinters slightly. Ash—pale red.
Cerussite, impregnated with lead-oxide, from Sambalpur, for assay.	GILLANDERS, ARBUTHNOT, & Co., Calcutta.	
Galena, from Sambalpur, for assay.	Ditto.	
7 specimens of minerals from Sikkim, for determination.	P. N. BOSE, Geological Survey of India.	A. Chalcopyrite and pyrite, with clay-slate and quartz. B. Talcose-schist with pyrite, chalcopyrite, bornite, copperas and blue vitriol with small traces of epsomite. C. Chalcopyrite and pyrite, in clay-slate. D. Talcose-schist. E. Pyrite. F. Quartz with peach and pyrite. G. Chalcopyrite and pyrite, in clay-slate.
6 specimens of minerals, for determination.	O. L. FRASER, Indian Museum.	(1) Fragments of quartz, and titaniferous iron-ore, with decomposed iron-oxides. (2) Granite with veins and strings of green epidote. (3) Fragments of hydrated oxides of iron. Pieces of dolerite with fresh plagioclase and augite. (4) Fragments of hydrated iron-oxide. Titaniferous iron-ore. (5) Quartz, with pseudomorphous cavities after micaceous iron-ore. (6) Quartz with films of specular iron-ore.

Calcareous conglomerate, from Gwalior, for determination. — COL. D. G. PITCHER, Gwalior.

The rounded fragments are almost wholly composed of calcic carbonate in a micro-crystalline or amorphous condition with large quantities of light green chloritic minerals in some, and hydrated iron-oxide in other fragments. The whole is cemented with distinctly crystallized calcite, the crystals in which invariably exhibit zones of ferruginous inclusions.

9 specimens of coal, minerals, &c., from the neighbourhood of Kalka, Simla district, for determination. — W. COLDSTREAM, Deputy Commissioner, Simla district.

	A. "Supposed to be from Kamli seam." Quantity received, 4 lb.	C. "Supposed to be from Tarla Silu." Quantity received, 1¼ oz.	D. "From Chandi [illegible]stream." Quantity received, 2¾ oz.	E. "From Dudra." Quantity received, 20¾ oz.
Moisture	1·98	4·04	9·72	1·40
Volatile matter	24·94	22·48	29·74	16·36
Fixed carbon	50·42	42·08	59·94	40·04
Ash	22·66	31·46	·60	42·20
	100·00	100·00	100·00	100·00
	Cakes, but not strongly. Ash—dark brown.	Does not cake. Ash—dark brown.	Does not cake, but sinters slightly. Ash—dark red.	Does not cake, but sinters slightly. Ash—brick red.

B. Carbonaceous shale

F. Ditto.

G. Ditto.

H. Pyrite and marcasite.

I. Alum.

Graphitic schist, from Towara, Black Mountain. — C. S. MIDDLEMISS, Geological Survey of India.

Moisture	·20
Volatile matter	2·96
Fixed carbon	10·04
Ash	86·80
	100·00

Ash—gray.
Quantity received, 14¼ oz.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of February, March, and April, 1891—concluded.

Substance.	For whom.	Result.								
15 specimens of coal, from the Daltonganj Coal-field borings, for assay.	T. D. La Touche, Geological Survey of India.		Sample No. 1. Boring No. IA. Coal at 17', Seam 7' 6" thick.	Sample No. 2. Boring No. I. Coal at 28', Seam 28' thick.	Sample No. 4. Boring No. II. Coal at 57', Seam 6' thick.	Sample No. 5. Boring No. IV. Coal at 29', Seam 4' thick.	Sample No. 6. Boring No. IV. Coal at 44', and at 74', Seam 2' thick.	Sample No. 11. Boring No. X. Coal at 36', Seam 2' thick.	Sample No. 12. Boring No. X. Coal at 74', Seam 4' thick.	Sample No. 13. Boring No. IX. Coal at 27', Seam 4' thick.
		Quantity received . .	1 lb. 2¾ oz.	6lbs.	1lb. 8¾ oz.	2 oz.	4 oz.	4½ oz.	10 oz.	11½ oz.
		Moisture . . .	6·00	2·40	3·00	10·00	5·68	3·48	5·68	6·80
		Volatile matter . .	23·90	8·64	13·88	28·40	16·68	10·22	13·72	26·86
		Fixed carbon . .	38·78	40·44	30·34	44·50	42·78	42·95	46·84	54·24
		Ash . . .	31·32	48·52	52·78	17·10	34·86	43·35	33·76	12·10
			100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
						Does not cake. Ash—light buff.				
		Sample Nos. 3. 7, 8, 9/1, 9/2, 10, 14, 15, and 16, carbonaceous shale.								
Chalcopyrite and pyrite, from Pache (near Pakyang) Sikkim, for copper.	P. N. Bose, Geological Survey of India.	Specimen L. Quantity received, 5½ oz. Contains 20·31 per cent. of copper (Cu.)								

Notification by the Government of India during the months of February, March, and April 1891, published in the "Gazette of India," Part I.—Appointment, Confirmation, Promotion, Reversion, and Retirement.

Department.	Number of order and date.	Name of officer.	From	To	Nature of appointment, &c.	With effect from	Remarks.
Revenue and Agricultural Department.	628 S., dated 26th March 1891.	H. S. F. Warth	...	2nd Grade Deputy Superintendent	Substantive.	10th January 1891.	

Notification by the Government of India during the months of February, March, and April 1891, published in the "Gazette of India," Part I.—Leave.

Department.	Number of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	Remarks.
Revenue and Agricultural Department.	486/8-7 S., dated 6th March 1891.	C. L. Griesbach	Privilege leave .	9th April 1891.	...	

Annual Increments to Graded Officers sanctioned by the Government of India during February, March, and April 1891.

Name of officer.	From	To	With effect from	No. and date of sanction.	Remarks.
	R	R			
Fritz Noetling	580	620	1st October 1890.	Revenue and Agricultural Department No. $\frac{614}{30-7}$-S., dated 21st March 1891.	

Postal and Telegraphic Addresses of Officers.

Name of officer.	Postal address.	Nearest Telegraph Office.
R. BRUCE FOOTE	Yercaud	Yercaud (Madras).
T. W. H. HUGHES	Mergui	Tavoy.
C. L. GRIESBACH	Calcutta	Calcutta.
R. D. OLDHAM	Calcutta	Calcutta.
P. N. BOSE	Gantok (Sikkim)	Darjiling.
T. H. D. LATOUCHE	Calcutta	Calcutta.
C. S. MIDDLEMISS	Abbottabad	Abbottabad.
P. N. DATTA	Calcutta	Calcutta.
F. NOETLING	Yenangyoung (Upper Burma).	Yenangyoung.
HIRA LAL	Calcutta	Calcutta.
KISHEN SINGH	Calcutta	Calcutta.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1891. [August.

Boring Exploration *in the* Daltongunj Coal-field, *Palamow; by* TOM D. LA TOUCHE, B.A., *Deputy Superintendent, Geological Survey of India.* (With a map.)

Introductory remarks.—The investigation of the Daltongunj coal-field by means of borings, carried out during the past cold weather, was undertaken with the object of testing the capabilities of the field for the production of coal in sufficiently large quantities to warrant the construction of a railway that should make the coal available for use in Upper India,—a partial exploration made under the supervision of Dr. Saise in 1890 having raised hopes that coal of good quality would be found in abundance, his estimate giving a total quantity of "not less than 161,377,000 tons of coal containing 11·7 per cent. of ash," The borings recently made have, I regret to say, led to the conclusion that the estimate made by Dr. Saise both as to the quantity and quality of the coal, was too favourable; and though there is undoubtedly a large amount of coal in the field, yet the conditions of its distribution are such as to render it extremely doubtful whether a sufficiently large output could be obtained to encourage the construction of a railway for the sole purpose of carrying the coal to other parts of India.

It will be unnecessary here to give any account of the physical features of the district of Palamow in which the coal-field under discussion is situated, as these have already been fully described by Mr. Hughes (Memoirs G. S. of I. Vol. VIII, Part 2), but the more accurate survey I was enabled to make of the area actually occupied by the coal-bearing rocks has led me to differ in some points from the conclusions arrived at by Mr. Hughes, and before discussing the borings, it will be advisable to draw attention briefly to the surface conditions in this area.

Surface rocks.—The coal-bearing rocks (shown by Dr. Feistmantel from their fossil contents to be of Karharbari age*) occupy an area of about 30 square miles in the valley of the Kod at its junction with its tributaries the Amanat and Durgnoti. On all sides they are surrounded by Talchir shales, the boundary being for the most part very obscure except on the north side, where it is marked by a strong fault, which brings the coal measures nearly into contact with crystalline rocks. Over the greater part of this area the rocks visible at the surface are coarse, friable sandstones, consisting almost entirely of angular or slightly rounded grains of quartz and more or less decomposed felspar, showing much false bedding, and often containing strings of

* Records G. S. of I. Volume XVI, page 175.

quartz pebbles; in fact, such beds as would be deposited in fairly shallow water by strong currents. These sandstones are for the most part horizontal or slightly undulating, such dips as are visible being seldom constant in amount for more than a few yards; and as they overlap the beds below them, sections of the latter in which the coal occurs are seldom obtainable.

Outcrops near Rajhera.—To the east of Rajhera a considerable roll in the strata has brought up the lower beds with coal, and subjected them to the denuding influences of the streams, so that in this part of the field a larger amount of coal is actually visible at the surface than in any other: for this very reason, however, it is evident that a large quantity of the coal has been destroyed and carried away, and what remains has so deteriorated by exposure to the atmosphere that it is probably not of much value. These remarks apply, of course, only to the coal at the base of the coarse sandstones; for the borings have shown that a lower seam occurs in this area, of considerable thickness and extent, which nowhere appears at the surface, and is consequently still intact. In the vicinity of Singra also the lower beds are exposed to some extent, and sections of the coal-seams are to be seen, but here they have not been denuded away to such an extent as in the Rajhera area.

Position of coal-bearing beds in the series.—Mr. Hughes appears to have considered (page 17 of his report) that the beds with coal exposed to the east of Rajhera were the basement beds of the coal-bearing series, and as they contain the most promising seams of coal it was of importance to determine whether they were really the bottom beds, as in that case the seams contained in them, if constant, might be reached by deep borings towards the centre of the field. It appears, however, that the southerly dip, seen in the Sadabu river to the east of Rajhera is not continuous, so that these beds extend towards the south at no great depth from the surface, and I imagine have been pierced in most cases by the borings; these, I consider, have shown conclusively that although coal or carbonaceous shale occurs throughout the field at or about the same horizon as the seams at Rajhera, yet the thickness and quality of the coal is not preserved; indeed, it is extremely difficult to correlate the various beds of coal passed through in the different borings with each other. Such conditions as these would obviously be fatal to the carrying on of mining operations on a very large scale, even though the quality of the coal were unexceptionable, which is by no means the case.

Faults.—With the exception of the boundary fault, already mentioned, which runs along the northern side of the field, and is crossed by a secondary fault near the quarry formerly worked by the Bengal Coal Company, there do not appear to be any that would interfere with the working of the coal, though small faults of a few feet throw, probably due to the settling down of the beds upon an uneven floor of crystalline rocks, are not uncommon,—such faults as these seldom show at the surface.

Trap.—Two intrusions of igneous rocks have been discovered within the area of the coal-bearing rocks since Mr. Hughes surveyed the field. One of these occurs at Singra, where it was found by Mr. Mathews, in the mines opened at that place, cutting across the coal seams from south-west to north-east, the coal in its vicinity being somewhat altered in texture. The dyke is vertical and in places from 12 to 15 feet thick; it may be traced for about half a mile from Singra across the Amanat, but, being much decomposed, it only appears on the surface at a few points. The other instance of intrusion was found by me in the northern part of the field, near the quarry worked by the Bengal Coal Company. Here the trap is highly vesicular, and occurs in two bosses or necks probably connected with each other, the sandstones and shales surrounding them being burnt to a deep red colour. Probably the greater disturbance of the coal measures east of Rajhera is due to the existence of these outbursts of trap, and it is not unlikely that they are connected with dykes beneath the surface which would render mining in the area near them extremely difficult.

The Borings.

The sites for borings were selected with a view to determining the question whether the coal seams visible in the outcrops near Rajhera and Singra are continuous throughout the intervening area, the prevailing horizontality of the strata rendering it possible to do this without having to bore to any great depth. A line was selected passing through the field from north-west to south-east; and borings, commencing at the outcrop seen in the Sadabu river near Rajhera, were put down at intervals varying from a half to one mile. The results are given below; and the accompanying map of the coal-field gives the positions of the borings on the main line and east and west of it. Two of the borings, Nos. V and VIII, had to be abandoned at 54 and 82 feet respectively, on account of running sand being met with; and Nos. IA and II were stopped owing to accidents to the boring tools. Besides these, seven wing borings were put down at various distances to east and west of the main line, so as to obtain some idea of the lateral extension of the seams. In nearly all cases coal or carbonaceous shale was met with at the base of the coarse sandstones forming the surface rocks, and this probably represents the seam exposed near Rajhera, corresponding also to the 4 feet seam now being worked by Messrs. Hodges and Radford at Singra. The section of this seam passed through in the various borings is shown in Tables I and II (see pages 145, 146), with the section exposed at the outcrop in the Sadabu river as given in Mr. Hughes' report, for comparison. It will be seen that in no two cases does the thickness of coal agree. It varies from 1 foot 6 inches in boring No. III to 7 feet 6 inches in No. 1 A., so that, although it would be easy, by assuming an average thickness, to calculate the total quantity of coal contained in the area enclosed by the borings, such an estimate would be utterly unreliable. I have taken the second seam from the surface in borings VI and VII as representing this continuous seam, since it appears that the topmost seam met with in those two borings is only of local development; in fact, it may be traced in the outcrops exposed in the Amanat and Jinjoi river, and is seen to be very irregular, containing only from one to two feet of coal, and that very shaly, so that in any case it may be neglected.

The second seam met with in the borings near Rajhera, which I have attempted to trace through the other borings in Table III, is of greater thickness in places, reaching as much as 29 feet in boring I; but in boring II, only two-thirds of a mile to the south, its thickness is reduced to 6 feet, and becomes still further reduced or replaced with carbonaceous shale still further to the south. This seam was formerly worked in the old pits belonging to the Bengal Coal Company near Rajhera and Pundua; and, as I am informed by Mr. Hodges, Engineer-in-Chief of the Mogulserai-Daltongunj Railway Survey, it was found to be about 12 feet thick, though in the Pundua pit it was much broken up, probably owing to its proximity to the boundary fault. The abnormal thickness of the seam in boring I, may possibly be due to faulting, which has doubled the actual thickness of the seam, but in that case the fault would require to be of the reversed type, which is not common in beds so little disturbed as these coal measures; and I could detect no signs of such a fault at the surface. I am inclined to think therefore that the coal is really 29 feet thick at this spot, but that it thins out more or less rapidly in all directions. Assuming, however, that the thickness of coal in this seam, over an area of one square mile east of Rajhera, is 9 feet, it would furnish a total quantity in round numbers of 9,000,000 tons; but this estimate should not be considered as in any sense an exact measurement of the total quantity of coal available from this seam, as it certainly extends, though diminished in thickness, to some distance beyond the area included in my calculation.

Concerning the seams found at a greater depth in some of the borings, little need be said; they are as a rule shaly, and with the exception of boring No. VII, where a seam of shaly coal, 6 feet thick, was passed through at a depth of 107 feet from the surface, none of them exceeds 3 feet in thickness, so that they may be neglected.

Quality of the coal.—Analyses of the most promising samples of coal extracted from some of the borings were made in the Geological Survey laboratory, and the results are given below. They are somewhat disappointing, the amount of ash in most of them being higher than is generally considered admissible in a serviceable fuel; but it should be remembered that boring samples are very liable to be contaminated with an admixture of mud and sand from the churning they are subjected to by the boring tools; and the coal is probably of better quality than it appears to be from these analyses.

TABLE I.—MAIN LINE BORING SECTIONS OF FIRST OR UPPER SEAM.

No. of Boring.	Outcrop, Sadabu R. (Hughes). *(for comparison.)*	IA.	II.	III.	IV.	VI.	VII.	VIII.
Depth of seam.	*Cropping out at surface.*	47′ 0″	21′ 0″	54′ 6″	29′ 0″	33′ 0″	43′ 0″	—
Section of seam	Coaly shale 2′ 4″	*Coal* 7′ 6″	Shale slightly carbonaceous. 7′ 0″	*Coal* 1 6″	*Coal* 4′ 0″	*Coal* 2′ 0″	*Coal* 3′ 0″	Shale 3′ 0″
	Coal . 0′ 1″	Carb. shale. 2′ 6″	*Coal* very shaly. 5′ 0″	Carb. shale. 7′ 0″	Shale slightly carbonaceous. 1′ 0″	Shale very carbonaceous. 4′ 0″	Carb. shale. 4′ 0″	*Coal* 4′ 0″
	Carb. shale 2′ 1″	...	...	...	...	Coal shaly. 1′ 0″	*Coal* 1′ 0″	
	Coaly shale 0′ 8″	...	...	...	...	...	Carb. shale. 1′ 0″	
	Carb. shale 0′ 10″	...	...	...	...	...	*Coal* 4′ 0″	
	Coal and Carb. shale. 5′ 0′	...	...	...	...	...	...	
Total thickness .	11′ 0″	10′ 0″	12′ 0″	8′ 6″	5′ 0″	7′ 0′	13′ 0″	7′ 0″

TABLE II.—WING BORING SECTIONS OF FIRST OR UPPER SEAM.

No. of Boring	IX.	X.	XI.	XII.	XIII.	XIV.	XV.
Depth of seam.	26′ 0″	36′ 0″	87′ 0″	—	93′ 0″	53′ 0″	67′ 0″
Section of seam	Carb. shale 1′ 0″ *Coal* 4′ 0″ Carb. shale 2′ 0″	Carb. shale 2′ 0″ Shale 5′ 0″ Sandstone 3′ 0″ Carb. shale 2′ 6″	Coal shaly 3′ 0″ *Coal* 4′ 0″ Slightly carb. 14′ 0″	... ...	Shale slightly carbonaceous. 5′ 0″ ...	Carb. shale 6′ 0″ ...	Carb. shale 6′ 0″ *Coal* 7′ 0″
Total thickness	7′ 0″	12′ 6″	26′ 0″	...	5′ 0″	6′ 0″	13′ 0″

TABLE III.

	MAIN LINE BORING SECTIONS OF SECOND OR LOWER SEAM.						WING BORING SECTIONS.	
No. of Boring.	I.	II.	III.	IV.	VI.	VII.	IX.	X.
Depth of seam	28′ 0″	57′ 0″	120′ 0″	71′ 0″	69′ 0″	78′ 0″	59′ 0″	70′ 6″
Section of seam	*Coal* 28′ 0″ Carb. shale 1′ 0″ ...	*Coal* 6′ 0″	*Coal* 4′ 0″	*Coal* shaly, 2′ 0″ Shale 1′ 0″ *Coal* shaly, 2′ 0″ Shale, sandy 6′ 0″ carbonaceous. *Coal* 2′ 0″	*Coal*, shaly 3′ 0″	*Coal*, shaly 2′ 0″ *Coal* 2′ 0″ ...	Carb. shale 40 *Coal* 10 Carb. shale 4′ 0″	Carb. shale 3′ 6″ Coal shaly 1′ 0″ *Coal* 3′ 0″
Total thickness	29′ 0″	6′ 0″	4′ 0″	13′ 0″	3′ 0″	4′ 0″	9′ 0″	7′ 6″

TABLE OF ASSAYS.

Number of boring.	I.	IA.	II.	IV.	IX.
Thicknss of seam.	28 feet.	7 feet 6 inches.	6 feet.	4 feet.	4 feet.
Depth from surface.	28 feet.	47 feet.	57 feet.	29 feet.	27 feet.
Moisture		6·00	3·00	10·00	6·80
Volatile matter (*exclusive of moisture*).		23·90	13 88	28·40	26.86
Fixed carbon	40·44	38·78	30·34	44·50	54·24
Ash	48·52	31·32	52·78	17·10	12·10
TOTAL .	100·00	100·00	100·00	100·00	100·00

Does not cake ash—light buff.

It would certainly be advisable, before condemning the coal on the strength of the analyses given above, to extract a sufficient quantity,—three or four hundred tons,—from the thick seam at Rajhera, to enable a reliable estimate to be formed of its quality, by testing it in steam boilers. It might be possible to utilise the old shafts near Rajhera for this purpose, but a certain amount of pumping would be required to clear them of the water which now nearly fills them.

The actual boring operations were carried out under the superintendence of Mr. Chirnside, Executive Engineer, Public Works Department, of whose energy and resource in overcoming the difficulties constantly arising in work of this nature, it is difficult to avoid expressing my appreciation. These difficulties were enhanced, in the present instance, by the inferior quality of the tools supplied; and it is entirely owing to Mr. Chirnside's continual exertions that the work was kept going without interruption till the close of the season.

APPENDIX.

Boring Records, Daltongunj Coal-Field season, 1890-91.

BORING No. I.

Strata passed through.	Thickness. Ft.	in.	Depth. Ft.	in.
Coal, shaly	1	6	...	
Sandstone, shaly	7	6	9	0
Shale, sandy	19	0	28	0
Coal	28	0	56	0
Shale, carbonaceous	1	0	57	0
Sandstone	11	0	68	0
Shale, carbonaceous	2	0	70	0
Sandstone	26	6	96	6
Coal, shaly	0	6	97	0
Sandstone, hard	24	0	121	0
Sandstone, shaly	15	0	136	0
Shale, carbonaceous	7	0	143	0

BORING No. IA.

Strata passed through.	Thickness. Ft.	in.	Depth. Ft.	in.
Sandstone, yellow and white, coarse	47	0	...	
Coal	7	6	54	6
Shale, carbonaceous	2	6	57	0
Sandstone, shaly	5	0	62	0
Coal, shaly	1	0	63	0
Shale, carbonaceous	11	0	74	0

BORING No. II.

Strata passed through.	Thickness. Ft.	in.	Depth. Ft.	in.
Sandstone, yellow, coarse	17	0	...	
Coal	1	0	18	0
Shale	3	0	21	0
Shale, slightly carbonaceous	7	0	28	0
Coal, very shaly	5	0	33	0
Shale	11	0	44	0
Sandstone, white	13	0	57	0
Coal	6	0	63	0
Shale	4	0	67	0
Sandstone	6	0	73	0
Shale, slightly carbonaceous	3	0	76	0
Sandstone, white, fine	5	0	81	0
Shale, sandy	5	0	86	0
Shale, slightly carbonaceous	3	0	89	0
Shale	2	0	91	0
Sandstone, white	11	0	102	0
Coal	1	0	103	0

BORING No. II—*continued.*

Strata passed through.	Thickness. Ft.	in.	Depth. Ft.	in.
Shale, carbonaceous, sandy	4	0	107	0
Sandstone	9	6	116	6
Shale	9	0	125	6
Sandstone	10	6	136	0

BORING No. III.

Sandstone, coarse	54	6	...	
Coal	1	6	56	0
Shale, carbonaceous	7	0	63	0
Shale, sandy	27	0	90	0
Sandstone, coarse	6	0	96	0
Sandstone, white, fine	15	0	111	0
Shale, sandy	9	0	120	0
Coal	4	0	124	0
Shale	26	0	150	0
Shale, sandy	9	0	159	0
Coal	2	0	161	0
Shale	18	0	179	0
Shale, sandy	14	0	193	0
Shale, carbonaceous	3	0	196	0
Shale, sandy	7	0	203	0
Sandstone	5	0	208	0
Shale, sandy	6	0	214	0
Shale, carbonaceous	6	0	220	0
Sandstone, shaly	9	0	229	0
Sandstone, coarse	9	0	238	0
Sandstone, fine	14	0	252	0
Shale	23	0	275	0
Sandstone	5	0	280	0

BORING No. IV.

Surface soil, yellow sandy clay	7	0	...	
Shale	1	0	8	0
Clay, light brown	5	0	13	0
Sandstone, yellow	10	0	23	0
Shale	3	0	26	0
Sandstone, fine buff	3	0	29	0
Coal	4	0	33	0
Shale, slightly carbonaceous	1	0	34	0
Sandstone, white	10	0	44	0
Coal, shaly	1	0	45	0
Shale, sandy	1	0	46	0
Sandstone, white, fine	11	0	57	0
Shale, sandy	2	0	59	0
Sandstone, white, with pyrites	12	0	71	0
Coal, shaly	2	0	73	0
Shale	1	0	74	0
Coal, shaly	2	0	76	0

BORING NO. IV—*continued.*

Strata passed through.	Thickness. Ft.	in.	Depth. Ft.	in.
Shale, carbonaceous, sandy	6	0	82	0
Coal	2	0	84	0
Shale, sandy	12	0	96	0
Sandstone	13	0	109	0
Shale	7	0	116	0
Sandstone	3	0	119	0
Coal	2	0	121	0
Shale, sandy	9	0	130	0
Sandstone, shaly	5	0	135	0
Coal, shaly	3	0	138	0
Sandstone	17	0	155	0
Sandstone, slightly carbonaceous	4	0	159	0
Sandstone, shaly	13	0	172	0
Shale	3	0	175	0
Sandstone, shaly	11	0	186	0
Shale, carbonaceous, sandy	8	0	194	0
Shale, slightly carbonaceous	13	0	207	0
Sandstone, very hard	8	6	215	6

BORING No. V.

Surface soil, sandy clay	15	0	...	
Sandstone, soft	39	0	54	0
Running sand	?		...	

BORING No. VI.

Surface soil	6	0	...	
Sandstone, coarse, yellow	6	0	12	0
Shale	4	0	16	0
Shale, carbonaceous	4	0	20	0
Coal, shaly	1	0	21	0
Shale, carbonaceous, sandy	2	0	23	0
Shale, sandy, with carbonaceous strings	10	0	33	0
Coal	2	0	35	0
Shale, very carbonaceous	4	0	34	0
Coal, shaly	1	0	40	0
Shale	6	0	46	0
Sandstone, partly shaly	23	0	69	0
Coal, shaly	3	0	72	0
Shale, sandy	4	0	76	0
Sandstone	41	0	117	0
Sandstone, carbonaceous, shaly	1	0	118	0
Sandstone, very carbonaceous	1	0	119	0
Sandstone, slightly shaly	5	0	124	0
Sandstone, carbonaceous shaly	1	0	125	0
Shale	3	0	128	0
Sandstone	13	0	141	0

BORING No. VII.

Strata passed through.	Thickness. Ft.	in.	Depth. Ft.	in.
Surface soil, yellow sandy clay	19	0	...	
Sandstone, white	3	0	22	0
Coal	2	0	24	0
Shale, carbonaceous	4	0	28	0
Sandstone, white	15	0	43	0
Coal	3	0	46	0
Shale, carbonaceous	4	0	50	0
Coal	1	0	51	0
Shale, carbonaceous	1	0	52	0
Coal	4	0	56	0
Sandstone, shaly	1	0	57	0
Shale	5	0	62	0
Sandstone, slightly shaly	4	0	66	0
Shale, sandy	2	0	68	0
Sandstone, shaly	10	0	78	0
Coal, shaly	2	0	80	0
Coal	2	0	82	0
Shale	1	0	83	0
Sandstone, slightly shaly	9	0	92	0
Sandstone, white	14	0	106	0
Shale, carbonaceous	1	0	107	0
Coal, shaly	6	0	113	0
Shale carbonaceous	3	0	116	0
Sandstone, shaly and hard	15	0	131	0
Shale, carbonaceous	1	0	132	0
Sandstone	21	0	153	0

BORING No. VIII.

Surface soil, yellow sandy clay and sand	37	0	...	
Sandstone	15	0	52	0
Shale	3	0	55	0
Coal	4	0	59	0
Sandstone, yellow	7	0	66	0
Shale	3	0	69	0
Sandstone, white	4	0	73	0
Running sand	9	0	82	0

BORING No. IX.

Surface soil, sandy clay	17	0	...	
Shale, carbonaceous	2	0	19	0
Sandstone, shaly	7	0	26	0
Shale, carbonaceous	1	0	27	0
Coal	4	0	31	0
Shale, carbonaceous	2	0	33	0
Sandstone	26	0	59	0
Shale, carbonaceous	4	0	63	0
Coal, shaly	1	0	64	0
Shale, carbonaceous	4	0	68	0

BORING No. IX—*continued.*

Strata passed through.	Thickness. Ft.	in.	Depth. Ft.	in.
Sandstone	6	0	74	0
Shale, carbonaceous	1	0	75	0
Shale, sandy	10	6	85	6
Sandstone, shaly	6	6	92	0
Shale, sandy	18	0	110	0
Shale, carbonaceous	1	0	111	0
Shale, sandy	3	0	114	0
Sandstone, white	20	0	134	0

BORING No. X.

Surface soil, sandy clay	13	0	...	
Sandstone	23	0	36	0
Shale, carbonaceous	2	0	38	0
Shale	5	0	43	0
Sandstone	3	0	46	0
Shale, carbonaceous	2	6	48	6
Shale, sandy	4	0	52	6
Sandstone, shaly	18	0	70	6
Shale, carbonaceous	3	6	74	0
Coal, shaly	1	0	75	0
Coal	3	0	78	0
Shale, sandy	16	6	94	6
Sandstone, with strings of pebbles	24	6	119	6

BORING No. XI.

Surface soil, sandy clay	44	0	...	
Sandstone, white	8	0	52	0
Sandstone, yellow	19	0	71	0
Shale	5	0	76	0
Sandstone, yellow and white	11	0	87	0
Coal, shaly	3	0	90	0
Coal	4	0	94	0
Shale, slightly carbonaceous	19	0	113	0

BORING No. XII.

Surface soil, sandy clay	15	0	...	
Sandstone, yellow	47	0	62	0
Sandstone, shaly	4	0	66	0
Shale, sandy	3	0	64	0
Coal	1	0	70	0
Sandstone	18	0	88	0
Shale	2	0	90	0

BORING No. XIII.

Strata passed through.	Thickness. Ft.	in.	Depth. Ft.	in.
Sandstone	93	0	...	
Shale, slightly carbonaceous	5	0	98	0
Sandstone	23	0	121	0

BORING No. XIV.

Surface soil, sandy clay	6	0	...	
Sandstone, shaly	19	0	25	0
Shale, sandy	28	0	53	0
Shale, carbonaceous	6	0	59	0
Sandstone, hard	9	0	68	0
Shale, sandy	43	0	111	0

BORING No. XV.

Surface soil, sandy clay	13	0	...	
Sandstone, yellow	23	0	36	0
Shale	4	0	40	0
Coal	1	0	41	0
Shale	5	0	46	0
Sandstone, shaly	7	0	53	0
Sandstone, white	14	0	67	0
Shale, carbonaceous	6	0	73	0
Coal	7	0	80	0
Sandstone, shaly	3	0	83	0

Death of DR. P. MARTIN DUNCAN, M.B. (*London*), F.R.S., F.L.S., F.G.S., *&c.*

In the Annual Report of the Survey for last year reference was made to the failing health of Dr. Duncan, who had, in his usual most kind and voluntary way, undertaken the study and description of a further collection of our Western India fossils which had been sent to England. Regarding the receipt of this collection, he wrote on the 24th of October last:—

"The big box has been opened, unpacked (a rare job), and the contents placed in a case and in drawers in a special room at the British Museum. With the exception of these drawers, the corals are arranged according to their groups, and I have described some striking forms. Probably three more visits to the Museum will enable me to separate the collection generically. The Echinos are very few.

"The collection from Jumara by Stoliczka is immense, and the duplicates are by the hundred. Now, I find species in it wonderfully representative of our lower Oolite (Bath and Infra-Oolite), and associated with them some which, from facies, I should place in the Corallien, such as a *Comoseris* closely allied to *irradians*. * * * * There will be the material for a good volume in the Palæontologia Indica, but not so large a volume as that of my Tertiary Corals.

"I have taken especial care to isolate and roughly classify the Kach corals, and to explain to Dr. Woodward that they belong to the Indian Survey, because in all probability before the species are all described I shall have gone to my eternal rest. I feel sad in thus writing with my mind as clear as ever it was, but almost contemporaneously with the arrival of the fossils, I became aware (*here follows an account of a consultation with his medical adviser*). I have given up everything, and your fossils are giving me the last pleasure in my life as a naturalist."

Thus ended the correspondence and collaboration of one whom we might almost claim as a colleague since 1864; and who was an esteemed friend of most of the retired and older members of the Survey. His memory must be still green among many men in India who attended his geological lectures at Cooper's Hill.

The touching and resigned conclusion of his letter told too surely of the coming end. He died on the 28th of May last, aged 67, after a very painful illness, which it is a consolation to think we had helped to lighten in a way he loved so well.

Dr. Duncan was Professor of Geology in King's College, London, and Lecturer on Geology to the Royal Engineering College, Cooper's Hill.

Besides several contributions relating to the invertebrate palæontology of India which appeared in the Quarterly Journal of the Geological Society, London, and in the Annals and Magazine of Natural History, he enriched the Palæontologia Indica with:—

THE SIND FOSSIL CORALS AND ALCYONARIA (1880).

and, in conjunction with Prof. W. Percy Sladen,

THE FOSSIL ECHINOIDEA OF SIND (1882-84)—

1. The Cardita Beaumonti Beds.
2. The Ranikot Series in Western Sind.
3. The Khirthar Series.
4. The Nari (Oligocene) Series.
5. The Gaj (Miocene) Series.
6. The Makran (Pliocene) Series.

THE FOSSIL ECHINOIDEA OF KACH AND KATTYWAR, (1883).

To the Records of the Survey he also contributed a "Note on the Echinoidea of the Cretaceous Series of the Lower Narbada Valley, with remarks upon their geological age," (1887), and "A description of some new species of Syringosphæridæ, with remarks upon their structure," (1890).

Contributions *to the* study *of the* Pyroxenic varieties *of* Gneiss *and of the* Scapolite-bearing Rocks[1]; *by* M. AL. LACROIX.—Ceylon *and* Salem. (*Translated by* F. R. MALLET, *late Superintendent, Geological Survey of India.*)

TRANSLATOR'S REMARKS.

The memoir, with the above title, appeared in the *Bulletin de la Société Française de Minéralogie* for April 1889.[2] As justly remarked by the author, the portion translated in the following pages gives the result of the first detailed microscopical work that has been devoted to the crystalline rocks of Ceylon and Salem. The reason for this is not far to seek. Of the different writers, quoted by M. Lacroix, who have occupied themselves with the geology of portions of Southern India, the earliest wrote in 1802, the latest in 1864—all of them, therefore, at a time when the modern science of micro-petrology was non-existent.

M. Lacroix's memoir being, in the main, devoted to certain special types of rock only, his work relating to the Indian region necessarily leaves a large field still untouched. I understand that it is his intention to enter upon this in a second paper at some future period. In the meantime, it is a distinct gain for Indian geology that the rocks within the scope assigned should have been studied in such detail by a petrologist so eminent as the author of '*Les Minéraux des Roches.*' It will be seen that the results obtained are both interesting and important, the occurrence of several remarkable types of rock having been established, and numerous additions made to our knowledge of Indian mineralogy. In how far the chronological classification suggested by M. Lacroix, founded on petrological analogies with the crystalline rocks of Western Europe, will bear the test of extended observation in the field, is a point that must be left to the geologists of Madras. That the problem is very far from a simple one appears from the observations hitherto made by the Geological Survey.

With reference to the following translation, there are one or two points that it may be well to allude to here.

While it was in hand, M. Lacroix furnished me with several additions, and a few alterations, which are distinguished from the original text by insertion in square brackets [ ].

While French mineralogists generally apply the term 'wernérite' to the group of closely related minerals, and 'scapolite' to the most prominent species, English authors, although not all in accordance with each other, most commonly use the names in the reverse sense. In the following pages, therefore, *wernérite* is translated 'scapolite,' and *vice versâ*.

The crystallographic formulæ are given in the original according to both Lévy's system and Miller's. As the former of these is, as a rule, less familiar to English mineralogists than Naumann's, the latter has been adopted in the sequel.

[1] Contributions à l'étude des gneiss à pyroxène et des roches à wernérite.

[2] Vol. XII, No. 4, p. 83.

The three principal indices of refraction, and also the three axes of optical elasticity of crystals, are represented in M. Lacroix's memoir by the letters n_g, n_m, n_p, which are translated as follows:—

$$n_g = \gamma \text{ or } = \mathfrak{c}$$
$$n_m = \beta \text{ or } = \mathfrak{b}$$
$$n_p = \alpha \text{ or } = \mathfrak{a}$$

The latter part of the 'Summary and Conclusions,' on "The geological distribution of the Scapolites," has not been translated, as it is entirely of a general character, without special reference in any way to Ceylon or India.

In conclusion, I must add that the thanks of the Geological Survey are due to M. Lacroix for kindly placing the original zinc-plates at its disposal. Hence the illustrations in the following pages are identical with those in the memoir as first published.

TABLE OF CONTENTS.

INTRODUCTION.

In the upper part of the gneissose series (*l'étage des gneiss*), in numerous regions, pyroxenic rocks occur which present a very peculiar facies. These rocks, often associated with hornblendic gneisses and amphibolites (*amphibolites*), have a granular structure more or less fine-grained; their mineralogical composition is generally very simple, but admitting of a number of varieties, due to the frequent variations in the chemical composition, and relative proportions, of the light-coloured constituent minerals (*éléments blancs*). These rocks, by some authors designated pyroxenites, are in this memoir called pyroxenic gneiss (*gneiss à pyroxène*). We will reserve the term 'pyroxenite' for rocks composed exclusively of pyroxene.

One of the characteristic traits of this class of gneiss is the frequent presence of minerals of the scapolite group. They play the same part as the felspars, which they accompany or replace. My researches show that the scapolites are very abundant in rocks in which they have been for a long time overlooked. I have been able to add a certain number of new occurrences of such rocks to those formerly known.

[1] Not translated.

No comprehensive memoir having been yet published on the scapolite-bearing rocks, I have added to the present one a description of two dipyre-bearing rocks coming, one from Norway, the other from Algeria. The dipyre-diorite of Norway being the result of the transformation of an olivine-gabbro, I have been led to study this latter rock, and, in consequence, a French occurrence of olivine-gabbro that I have discovered in Loire Inférieure.

Most of the rocks described have been collected by myself, during the course of work which has been entrusted to me, either by the Minister of Public Instruction, or by the 'École des Hautes Etudes.' Generally speaking, I have devoted myself to the study, not only of the pyroxenic gneisses, but also to that of the rocks which are intimately associated with them in the localities visited.

This work is only the prelude to a comprehensive study of the basic gneisses that I propose to carry out. I must here express my best thanks to MM. des Cloizeaux, Fouqué and Michel-Lévy, who have aided me with their advice, and to the *Société Minéralogique*, which has undertaken the publication of this memoir.

CHAPTER VII —GNEISS OF CEYLON AND OF THE SALEM DISTRICT.

Historical; and Geographical distribution.

The rocks which have served as the basis for the present chapter are preserved amongst the collections of the 'Collège de France' and of the 'Muséum d'Histoire naturelle'[1]; a portion of them was collected in 1819 by Leschenault de la Tour, who travelled on behalf of the Museum. Some of them also formed a part of de Bournon's collection, preserved in the 'Collège de France,' and are the originals which that *savant* made use of for his monograph on Corundum.[2]

The Ceylon rocks came from the region which extends from the town of Colombo, on the west coast of the island, as far as Kandy.

The rocks of the Indian peninsula were collected in the district of Salem (Madras Presidency).

The town of Salem is built, at an altitude of 900 English feet, upon a plateau watered by the Cauvery, and dominated to the north by the Shevaroy mountains, which rise to [an average elevation of 4,500 feet, the highest point being 5,410].

The rocks and minerals included in de Bournon's collection are labelled as coming from Salem "on the Coromandel Coast," although Salem is over 100 miles from the sea, to the W. S. W. of Pondicherry.

Occupied, as he mainly was, with botanical and zoological pursuits, Leschenault has given very few stratigraphical details concerning the region he travelled through.[3]

[1] Thanks to the kindness of MM. Daubrée and St. Meunier, I have had full opportunity for studying the specimens in the Museum collections.

[2] "*Description of the Corundum stone and its varieties.*"—Philosophical Transactions, London, (1802), p. 232.

[3] ["*Rélation d'un voyage à Karikal et à Salem.*"—Mém. du Muséum d'hist. natur. de Paris VI, (1820) 329-348.]

The rocks from the neighbourhood of Salem, and those from Ceylon, present a striking analogy from a petrographical point of view. As far as we know, they have never been the subject of any petrographical work.

De Bournon [1] confines himself to a description of the minerals accompanying the corundum. Newbold,[2] Campbell [3] and Balfour [4], devoting their attention to the same subject, are still more cursory.

In 1864 William King and Robert Bruce Foote published a memoir "On the geological structure of portions of the districts of Trichinopoly, Salem and South Arcot, Madras" [5] which gives some geological and stratigraphical information respecting the region near Salem. The gneissic rocks in question, however, are not treated on very fully.

In Greenough's maps, and in that more recently published by the Geological Survey of India,[6] the region with which we are concerned is tinted uniformly as metamorphic.

The 'Manual of the Geology of India' [7] does not enter into more detail, giving merely references to [8] the preceding memoirs.

To the south of Salem the Cauvery is bordered by small sterile eminences without trees. The Salem plateau is formed of small undulations covered with jungle until the Baramahal plateau is reached, and the Shevaroy mountains which rise above it.

Stratigraphy.

King and Foote describe, in the Salem region, several varieties of quartzose or hornblendic gneiss, the latter of which are associated with cipolins; these rocks are traversed by dykes of porphyrite.

Hornblendic rocks predominate, and one of them, designated "Syenitoid gneiss," is the oldest rock in that part of the country. Limestone is of rare occurrence.

The order of succession of the different rocks enumerated is not given.

Judging by means of analogy with the gneissic rocks of the regions that we have already described,[9] we shall indicate, broadly, the probable order of succession of these diverse rocks, or, at least, we shall point out the existence, in the area under discussion. of rocks that should be classed with ζ^1, ζ^2 and x of the detailed geological map of France.

From a petrographical point of view we may distinguish two series, that of the acid, and that of the basic, gneisses.[10]

[1] *Op. cit.*

[2] Journ. Roy. As. Soc., VII (1842), 219.

[3] Cal. Journ. Nat. Hist., II (1842), 281.

[4] Selec. Rec. Govt. Madras, XXXIX (1857), 91.

[5] Memoirs of the Geological Survey of India, I V (1864).

[6] Preliminary sketch of the Geology of India, Calcutta (1877).

[7] I and II, Medlicott and Blanford; III, Ball; IV, Mallet.

[8] It would be more correct to say "condensed accounts of the most important information contained in."—*F. R. M.*

[9] In the chapters not translated.—*F. R. M*

[10] We do not include the serpentinous and dolomitic rocks forming the chalk hills near Salem, that the preceding authors have spoken of, but of which we have no specimens at our disposal.

The acid gneisses are divisible into three well-marked groups:—

(*a*) ***Biotite and sillimanite-gneiss;***
(*b*) ***Garnetiferous leptynite;***
(*c*) ***Granulitic microcline-gneiss.***

The first includes some remarkable accidental rocks (andalusite- and sillimanite-bearing exceptional rocks).

In the second group are varieties sometimes containing pyroxene, and marking a passage into the more basic rocks; they recall, in a general way, the leptynites of the central plateau of France, but with a larger proportion of garnet.

Finally, the third group includes, very probably, granulites (*granulites*) that a mere laboratory examination does not suffice to distinguish with certainty from granulitic gneiss.

Whilst the rocks of the two first groups are especially abundant at Colombo, those of the [third] are particularly frequent at Kandy, and only occur accidentally in the neighbourhood of Salem (probably in the form of granulites).

These rocks are pierced by veins of coarsely crystalline pegmatite, so frequently found in all gneissose regions. By the great development of minerals, and the nature of the constituent felspar, they recall the pegmatites of the south-east coast of Norway.

The basic gneissose series is much more varied. It includes—

Pyroxenic and hornblendic gneisses (a).
Pyroxenic and hornblendic gneisses (b).
Anorthite-gneiss.
Cipolins.

The groups *a* and *b* differ from each other in the nature of their pyroxene, and *b* admits of a four-fold division in accordance with the variety of hornblende which accompanies or replaces the pyroxene.

In the same way the anorthite-bearing rocks can be divided into several sub-groups founded on the presence or the predominance of scapolite, garnet, pyroxene, or hornblende.

Some rocks of exceptional types are closely related to them, such as that composed of wollastonite, wernerite, and garnet.

Looked at stratigraphically, it is easy to see the analogy between all the acid gneisses and those of the series distinguished by the letter ζ^1 in the geological map of France. The pyroxenic and hornblendic gneisses *a* should be included in the same series.

In the group *b* certain types are closely connected with those of the first, whilst most of them are higher in position. Their age is apparently that of the pyroxenic gneiss of Brittany, the position of which, in the upper part of the gneissose series, is well established.

The rocks described further on, having anorthite, pyroxene, and scapolite as constituents, are closely equivalent to the scapolite-bearing pyroxenic gneisses of Loire-Inférieure and of Waldviertel. The same may be said of the cipolins which are associated with them.

Above these gneisses are found mica-schists of variable composition, closely comparable to the French and Alpine mica-schists of ζ^2; as the chloritic and sericite-schists are analogous to those of κ in the same region.

The succession of these different rocks may therefore be represented as in the following table, which indicates, at the same time, the order adopted in describing them :—

- Pyroxenic and hornblendic gneiss (*a*).
- Biotite and sillimanite gneiss.
- Garnetiferous leptynite ; pyroxenic granulitic gneiss.
- Granulitic microcline-gneiss.
- Pyroxenic and hornblendic gneisses (*b*).
- Anorthite and pyroxenic gneiss.
- Cipolins.

ζ^2 { Hornblendic mica-schist.
Grünerite mica-schist.
Fuchsite mica-schist.
Chloritic mica-schist. }

κ Sericite-schists, talcose and chloritic schists, quartzites.

Acid Gneisses.

(*a*) *Biotite- and Sillimanite-gneiss.*

These gneisses are identical in Ceylon and in Salem. They are rich in black mica, and possess a freely *rubanée*[1] structure.

The *black mica, garnet*, and *oligoclase* form thin layers, separated by seams of white translucent quartz, often mixed with oligoclase, and sometimes attaining several centimetres in thickness. In addition to these constituents, sillimanite frequently (Colombo) occurs in the micaceous layers. The crystals of sillimanite lie parallel to the foliation of the rock. These gneisses are, at times, much crumpled.

In some cases the felspar is very deficient, and the rock is composed almost exclusively of black mica, garnet, and sillimanite.

Microscopical examination discloses the presence of the following minerals: *apatite, magnetite, zircon, sillimanite, biotite, almandine garnet, oligoclase,* [*orthoclase*], *quartz*, and occasionally *hornblende* [and *graphite*] (Salem).

The *apatite, zircon*, and *magnetite* only play a subordinate part The *sillimanite* occurs in crystals elongated in the direction of the zone $\infty \bar{P} \infty$ $\infty \breve{P} \infty$ (100), (010) with extremely numerous cleavage-fractures parallel to oP (001). The crystals are always distinct, and sometimes attain a length of one centimetre, with a breadth of a quarter of a millimetre.

They do not form a tangle of little needles, as in the granulitic gneisses of the central plateau of France, and of most gneissose regions. They possess all the characteristic properties of sillimanite.

The *garnet* belongs to the almandine variety ; currant-red macroscopically, it is but faintly tinged with bright pink in thin sections.

The *biotite* occurs in scales, without definite form, about 2 millimetres in diameter. It is sensibly uniaxial. Pleochroic aureoles around inclusions of zircon are not uncommon. The pleochroism is most intense, with—

$\mathfrak{c}$ and $\mathfrak{b}$, dark black-brown.
$\mathfrak{a}$, bright yellow.

Often the absorption is so great, parallel to $\mathfrak{c}$ and $\mathfrak{b}$, that the plate is quite opaque to the rays vibrating in those directions.

[1] [*Roches rubanées* = "non-schistose rocks in which some of the constituents are disposed in parallel planes."]

The felspar is oligoclase in large hemitropic lamellæ on the albite- and pericline-types. It is very pure, free from inclusions of mica, but often filled with granules of *quartz de corrosion*[1] less than the $\frac{1}{25}$th of a millimetre in size and distributed in great numbers through one and the same crystal.

The *sillimanite* and *biotite* are intimately associated; [graphite, in hexagonal spangles, accompanies the mica]. The first of these two minerals has crystallized between the leaves of the second in such a way that on fractures perpendicular to the foliation of the rock the crystals of sillimanite may be seen to alternate with the scales of mica.

It was during the crystallization of these two minerals, and before it had finished, that the garnet was formed. In fact, numerous patches (*plages*)[2] of sillimanite and of biotite are noticeable completely, or partially, enclosed in the garnet, and, on the other hand, there are crystals of garnet evidently formed prior to the biotite, which has been moulded on them (*qui les a moulés*)[3].

Facts of a similar kind will be often described in the course of the present memoir. Whilst in the eruptive rocks most of the constituent minerals have a relatively fixed period of crystallization, and the order of succession is sensibly the same in a given rock, in the gneissose series under consideration, we shall see continual oscillations in the order of crystallization of the minerals, and that, not only in the different types, but also in one and the same rock.

The dark green *hornblende* is only found accidentally and in very small quantity; there is never a passage into hornblendic gneiss, such as occurs amongst the gneisses described further on.

After the crystallization of the felspar that of the quartz took place, which is moulded on all the other constituents of the rock in the same way as the quartz in granite.

When the rock is altered, the felspar becomes charged with damourite, and the mica changes to chlorite.

Exceptional Rocks.

Amongst the accidental mineralogical varieties that the gneisses of Ceylon, or of Salem, present, a special place should be given to the *andalusite-* and *sillimanite-*bearing rocks, and to those containing *sillimanite* and *corundum*, which are represented by large specimens in the collections of the *Collège de France* and of the Museum.

[1] [By *quartz de corrosion* French petrographers mean the quartz that is met with in divers minerals (and especially in the felspars) in the form of tears with curved and vermicular outlines, slightly resembling the quartz of graphic pegmatites, but without the regularity of the latter. The name of *quartz de corrosion* has been given to it on account of its probable secondary origin The minerals that enclose it are believed to have been corroded by the solutions that have deposited the quartz.]

[2] [*Plage* = "a continuous portion of mineral in a rock, having uniform optical properties over a certain area."]

[3] [*J'emploie 'mouler' dans le sens d'entourer, le minéral moulé étant antérieur au minéral moulant.*] The equivalent of *mouler* in this sense is "to be moulded on or around."—*F. R. M.*

The first comes from King's Fort, about 50 miles (*20 lieues*) west[1] from Colombo, as well as from the neighbourhood of Salem.

With the naked eye one may recognize flesh-red andalusite, in long striated prisms amongst which felspar is developed, quartz, sillimanite, and damourite. In other instances sillimanite predominates, owing to which the rock is extremely tough; there are specimens of this series, formed exclusively of sillimanite, which have served for the description of fibrolite given for the first time by de Bournon[2].

When microscopic sections of these specimens are examined, one immediately remarks the curious association of andalusite and sillimanite that I have recently described,[3] and which has been since noticed by MM. Michel-Lévy and Termier[4]; an association in which the two minerals have their crystallographic axes parallel, and in which they are easily distinguished by their double refraction and the different positions of their principal indices—

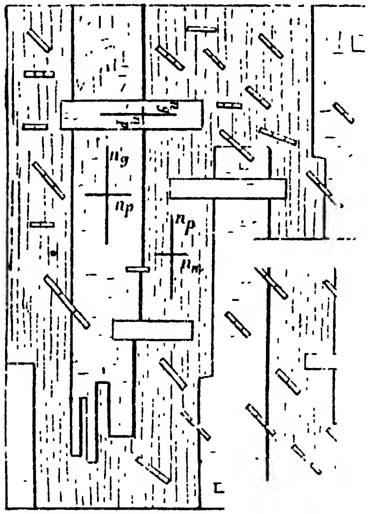

Fig. 1. Association, with parallel axes, of andalusite and sillimanite (Ceylon).[5]

There are, in addition, groupings of sillimanite at angles of 60° and 90°. Figure 46 illustrates this association.

The andalusite is intensely pleochroic, with—

c, b, } greenish white, almost colourless.
a, bright flesh-red.

This pleochroism is variable in intensity, and sometimes only exists in the state of faculæ. The cleavages ∞ P. ∞ P. (110) (1$\bar{1}$0) are well marked.

[1] *Sic*; probably a slip of the pen for east. It may be remarked here that the localities, bearings and distances, given by M. Lacroix, are those on the labels attached to the specimens.—*F. R. M.*

[2] *Description of the corundum stone and its varieties.*—Phil. Trans., 1802, p. 289.

[3] Bull. Soc. Minér. XI (1888), 150 and XII (1889), 59.

[4] *Idem*, XII (1889), 56.

[5] In the above illustration n_g = c, n_m = b, n_p = a.—*F. R. M.*

As previously remarked, the *sillimanite* is associated with andalusite: in some cases it forms crystals measuring 0·30 millimetres and well adapted for optical examination; in others little needles form closely felted aggregates, with irregular extinction; these are found in groups (*bandes*) or flakes (*flammèches*) both in the andalusite and in the felspar. [Some specimens that I have examined include corundum and rutile. The latter forms rounded grains, or crystals greatly elongated in the direction of the vertical axes, and orientated in the sillimanite and andalusite in such a way that the vertical axes of the two minerals are parallel.]

From one specimen I obtained a fragment, about 3 centimetres long by 2 broad, composed of crystals, measuring 3 or 4 millimetres, lying side by side in the direction $\infty \mathrm{P} \infty$ (100), with a degree of parallelism sufficient to give a section o P. (001) homogeneous from an optical point of view; this has served for measuring the principal indices by the method of total reflexion (sodium light).

The plane of the optic axes is parallel to $\infty \bar{\mathrm{P}} \infty$ (100): the bisectrix is positive c and normal to o P. (001)—

$$\gamma = 1{\cdot}678$$
$$\beta = 1{\cdot}659$$
$$\alpha = 1{\cdot}658$$

whence $\gamma - \alpha = 0{\cdot}020$. Dispersion strong, $\rho > v$.

This *sillimanite* encloses only a little biotite and corundum. A quantity of pure material, sufficient for an analysis (*a*), was obtained by treatment with boiling hydrochloric acid, hydrofluoric acid, and liquids of high specific gravity, successively. The analysis of sillimanite (fibrolite) from the same rocks, executed by Chenevix, is given in column (*b*)—

	(*b*)	(*a*)
Silica	38·00	39·45
Alumina	58·25	60·58
Ferric oxide	0·75	
	97·00	100·03
Specific gravity	3·214	3·24

The white mica is a damourite, the divergence between the axes of which is about:

$$2E = 35°$$

It occurs in laminæ on the crystals of andalusite, following the asperities and depressions of the latter; further, thin sections of the rock show them pierced with holes like a skimmer (*écumoir*). Frequently the white mica is developed around the jagged patches of biotite, the crystallographic orientation being common to the two micas.

The most interesting fact to notice with reference to this rock is the mutual relation of the minerals which compose it.

The *andalusite*, associated with sillimanite, occurs in large crystals often eaten away, corroded, and surrounded by a great number of little fragments orientated upon the principal patch: they seem to indicate corrosion *in situ* [or an impeded crystallization]. In other cases it is riddled with holes filled with quartz.

The felspar, which is *oligoclase*, has crystallized in large patches in the spaces left by the silicates of alumina: the quartz plays a similar part, occurring in rounded grains, generally of small size.

The *sillimanite* in capillary aggregates is also met with in the felspar; non-twinned patches much resembling cordierite are of frequent occurrence: although such an association is extremely probable, I have not evidence sufficient to clearly establish the presence of this mineral.

Sometimes the andalusite is embedded in a crystal of felspar; their vertical axes being coincident. By lowering the condenser of the microscope, the andalusite may be clearly observed to show out more strongly refractive.

The second interesting rock is a mixture of *corundum* and *sillimanite*.

The most remarkable specimen that I have had the opportunity of examining is composed equally of violet-pink coloured, granular corundum, and of reddish yellow sillimanite; the rock possesses a high specific gravity; with the naked eye the sillimanite may be observed distributed through the corundum in crystalline tufts, converging towards a centre. The pearly cleavage $\infty\bar{P}\infty$. (100) is very brilliant.

It is almost impossible at first to recognize the sillimanite. The rock, when examined in microscopic sections, shows the following structure: the corundum is made up of little rounded grains without distinct form, irregularly disseminated through large patches of sillimanite remarkable for the eminence of the cleavage ($\infty\bar{P}\infty$(100). There are none of those tangles of fine needles so common in the preceding rock; the crystals are always largely developed. Often, however, '*moirées*' extinctions indicate multiple groupings. The plane of the optic axes is parallel to $\infty\bar{P}\infty$.(100); the bisectrix is positive c and normal to oP. (001) with:

$$2E = \text{about } 35^\circ$$

and a strong dispersion with $\rho > v$.

[In one specimen the corundum, which is associated with large crystals of sillimanite, occurs in crystals which are flattened parallel to oP. (0001), and are rich in gaseous inclusions, and in inclusions of rutile disposed in parallelism to the base oP.(0001). The rock includes large patches of rutile surrounding the crystals of sillimanite. Further, tourmaline occurs, which is dark black-brown, and strongly dichroic in microscopic sections, and grouped with the corundum in such a way as to produce a fine *ophitic* structure.]

One difficulty in the way of diagnosis lies in the impossibility of obtaining sections of equal thickness; the presence of corundum in little particles, in fact, renders work on these rocks very difficult. Thanks to the well-known skill of M. Yvan Werlein, I have been enabled to obtain some good slides.

The double refraction is:

$$\gamma - \alpha = 0{\cdot}020$$

There is, however, no doubt as to the identity of this mineral with sillimanite.

About one gramme has been separated, by means of liquids of high specific gravity, from corundum, and from a small quantity of rutile which accompanies it, washed with boiling hydrochloric acid, and submitted to analysis. It is then of a violet-gray colour and transparent. The mineral is infusible before the blow-pipe, and insoluble in hydrofluoric acid.

Analysis gave practically the same results as those which have been recorded above.

[Since first writing this memoir, I have discovered in the Pyrenees of Ariège, in the rock-mass of St. Barthelemy, andalusite-bearing granulites (pegmatites) in thin veins piercing the gneiss. Corundum is there also associated with the andalusite.[1] It is probable that the exceptional rocks, just described, present themselves under similar geological conditions, instead of occurring, as I supposed at first, as accidental rocks in the gneisses themselves.]

De Bournon describes, in connection with indianite[2] (anorthite), the occurrence of sillimanite (fibrolite) in association with corundum. It seems evident that the author confounds the two rocks (acid gneiss and anorthite gneiss) in which, as Newbold[3] also attests, corundum is found.

The gneisses that occur [with] the sillimanite-gneiss present great difficulties in their delimitation. They are very abundant both in Ceylon and Salem. In the latter, however, more basic rocks (pyroxenic and hornblendic gneisses, anorthite bearing rocks) predominate.

Granulites composed of large crystals (pegmatite) occur in these regions, but independently of these rocks, eruptive granulites are found which it is not possible to distinguish, in the laboratory, from the granulitic gneisses which accompany them and into which there is a gradual passage. I have met with this difficulty in more than two hundred specimens of these rocks that I have examined.

They present the most varied aspects: sometimes relatively coarsely crystallized, sometimes nearly compact, in some cases they possess a well-marked stratified structure, in others they are granular. Some are composed almost exclusively of quartz, others contain scarcely any. They may, however, be classified in two groups.

One of these is very rich in garnet, and contains a little biotite; the dominant felspar is oligoclase.

The other is poor in, or without, garnet and biotite: microcline is the principal or only felspar.

The first, which is much the more schistose, approaches towards biotite- and sillimanite-gneiss; the second towards the granulites, and it is in this group that the granulites must be included that the imperfect means at my disposal do not enable me to separate with precision.

These are the groups (*b*) and (*c*) tabulated above.

(*b*) *Garnetiferous leptynites.*

The garnetiferous leptynites are especially largely developed in Ceylon, both at Colombo and Kandy.

They are of a bright colour, white or pink, and particularly rich in currant-red garnets, varying from the size of a pea to that of the head of a pin.

Although very variable in texture, the rock is extremely uniform in composition. There are present rutile, zircon, garnet, biotite, oligoclase, orthoclase, and quartz.

The felspars are often clouded (*troublès*) and rich in micaceous inclusions; the garnet occurs in rounded forms, hollowed with sinuous cavities filled with the white minerals of the rock.

[1] *Contributions à l'étude des roches métamorphiques et éruptives de l'Ariège.*—Bulletin des services de la carte géologique de la France, No. 11, C. II, 17,1890.

[2] *Op. cit.*, p. 289.

[3] Jour. Roy. As. Soc., VIII, 153.

The biotite, in little elongated laminæ, is very irregularly distributed, and is frequently wanting.

Some varieties of the rock are nearly compact, others, on the contrary, are somewhat largely crystallized. The schistose structure is marked by the orientation of the laminæ of mica and that of the garnet.

The structure is similar to that of the leptynites of the gneiss of the central plateau of France, and does not present anything special.

Pyroxenic leptynite.

At about three miles to the north of Colombo, on the cliffs bordering the sea, a variety of the preceding rock is found, which, owing to the presence of green strongly pleochroic, pyroxene, passes into the first of the pyroxenic gneisses which will be described further on.

Sometimes the rock is extremely compact, with a greenish-yellow colour, and slightly resinous appearance (it is then formed exclusively of quartz and of oligoclase, with very little garnet and pyroxene); sometimes it is largely crystallized, and composed of quartz, oligoclase, pyroxene, and felspar.

It is generally singularly free from weathering. Petrographical examination discloses, in addition to the minerals just enumerated, dark green spinel in large patches, often mixed with magnetite, as well as zircon in rounded crystals.

The *pyroxene* belongs to the very ferruginous and pleochroic variety which will be described some pages further on; that alluded to here, however, is more feebly doubly-refracting; the crystals are often broken, and in the fissures there is developed, after the manner of chrysotile in olivine, a greenish-yellow pleochroic mineral, with a maximum of absorption in the yellow tints parallel to c and to the elongation. The extinction is longitudinal: $\gamma - \alpha$ = about 0·025.

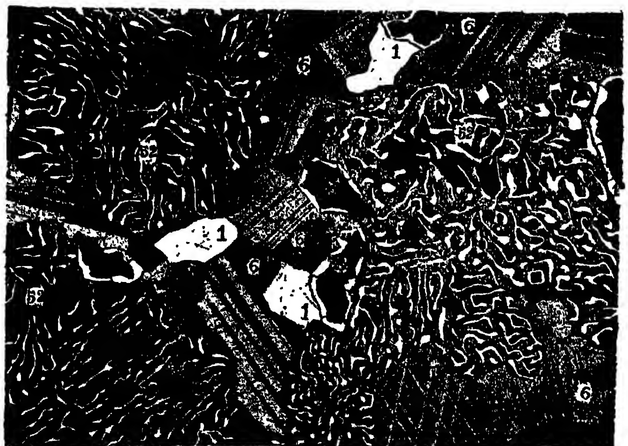

Fig. 2. Pyroxenic leptynite (Ceylon).

1, Quartz; 6, Oligoclase; 29, Magnetite with border of quartz; 52, Product due to the alteration of [cordierite] with vermicular quartz.

[Sometimes the pyroxene is completely transformed into this substance. In many specimens I have observed a yellowish secondary mineral, containing fine vermiculations of quartz, representing an elegant micro-pegmatite: although this mineral possesses much more feeble double refraction than the alteration-product of the pyroxene, I had been led to refer it to the same substance, and it is so called in the explanation to Fig. 47. Since this memoir was written, I have had numerous microscopic sections of this rock cut, and I have satisfied myself that the yellow, but slightly doubly refractive, substance represented in the figure, is different from the pyroxene alteration product, and ought to be attributed to the decomposition of *cordierite*. I have found specimens in which the cordierite is absolutely unaltered. It is markedly differentiated from the felspars by all its optical properties. Inclusions of zircon are abundant in it, which are surrounded by pleochroic aureoles of a fine golden yellow. I believe that pegmatoidal associations of cordierite and quartz have not been described hitherto.]

(c) *Granulitic microcline-gneiss.*

This last group is more artificial than the preceding one, and probably includes some eruptive granulites that cannot be diagnosed with precision by petrographical analysis alone. The schistose structure is less accentuated than in the preceding rocks. These rocks are especially abundant in the vicinity of Kandy, and are likewise met with in the neighbourhood of Salem.

They are of a bright, often pink, colour; generally poor in oligoclase and in black mica, and very rich in orthoclase and, above all, in microcline.

The quartz is more individualized than in the preceding gneisses, and is often present in the granulitic state (*à l'état granulitique*).

The microcline is very abundant: it has been in general the last of the felspars to consolidate. It is of remarkable purity, being nearly always free from inclusions of albite or oligoclase.

All the varieties in the appearance of the cross-hatched twinning characteristic of this felspar, described by M. des Cloizeaux[1], may be observed. The extinction-angles are about 15° on oP.(001) and about 7° on ∞P̆∞.(010).

Orthoclase sometimes occurs alone in large, bright, pink-coloured plates. An interesting fact that should be noticed with reference to these rocks, lies in the existence of much *quartz de corrosion* in the felspars, accompanied or replaced, by elongated inclusions, having their principal axes parallel to the vertical axis of the felspar.

In the sections ∞P̆∞.(010) the inclusions have the form of long spindles more strongly refractive, and with greater double-refraction, than the felspar. In the sections oP.(001) these inclusions (cut transversely), are rounded, and of small diameter. It is clear, therefore, that they are not distributed in relation to determinate faces of the prismatic zone, but that they are irregularly disseminated (Fig. 3).

Frequently they assume vermicular forms, and are so abundant that in parallel polarized light it is difficult to measure the extinction-angle of their host.

[Their extinction is different from that of the felspar which encloses them. I have ascertained, beyond doubt, that their refraction (contrary to what I thought at first) is the same as that of the quartz of the rock, and they should probably be regarded as composed of quartz. They constitute, then, a particular form of the *quartz de corrosion* described on p. 8].

In some specimens all the felspars, without exception contain them. They are

[1] Ann. Chimie et Physique, 5me Sér., Vol. IX (1876).

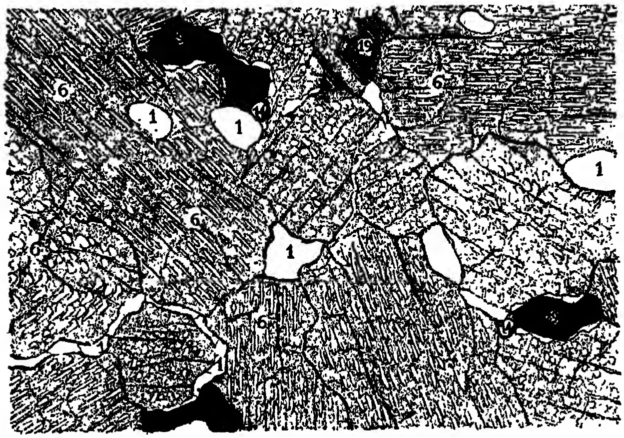

Fig. 3. Felspar inclusions (Salem).
1, Quartz; 6, Oligoclase with fusiform inclusions; 14, Sphene; 29, Magnetite surrounded by quartz.

equally to be found in the felspars of the pegmatites, and especially in the variety of orthoclase known as moonstone. [* * *]

Numerous crystals of felspar are filled with *quartz de corrosion.* The quartz is generally developed on the surface of the crystals, aud penetrates thence to the interior, where it forms fine vermiculations in connection with the quartzose peripheral zone. In certain cases these little quartzose canals increase in size, and the crystal of felspar is then formed only of débris included in a preponderating amount of quartz (*noyés dans le quartz*) (Fig. 4).

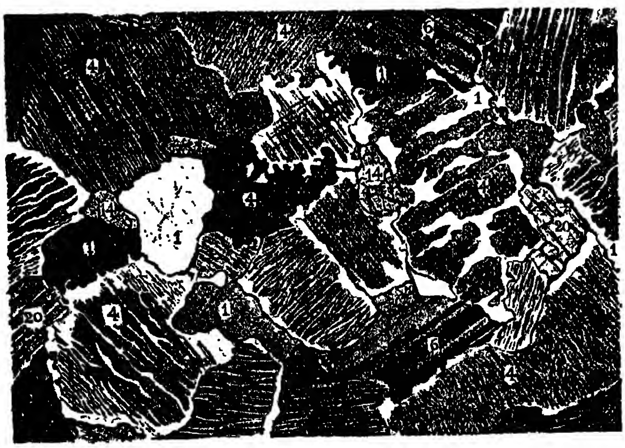

Fig. 4.—Microcline gneiss (Ceylon).
1, Quartz. 4, Quartzified microcline.
6, Oligoclase. 20, Pyroxene.

In other, and rarer, cases, the quartzification does not reach the centre of the crystal, and does not begin by a quartzose border.

I may further remark that the oligoclase is often free from this species of alteration, which is localized in the orthoclase, and, above all, in the microcline. Figure 4 illustrates the principal modes of quartzification.

PEGMATITES.

The pegmatites are found in Ceylon, and in the neighbourhood of Salem, at Petalia [53 miles (22 *lieues*) south-west from Salem], and at Perindoré[1]: they are largely crystallized, composed of microcline of bright pink tints, or green (amazon-stone), oligoclase, albite, and a black mica in large plates.

The pink microcline is often mixed with oligoclase; the two felspars being associated in the usual manner, with cleavages common to the two minerals.

Together with quartz it forms graphic pegmatites. The cross-hatched twinning of the green microcline (amazon-stone) is extremely fine and close. Sections parallel to oP.(001) produce, in parallel polarized light, an appearance resembling that of a finely crumpled texture: sometimes, even, the bands are so narrow that there is but an uncertain extinction.

Where the bands are sufficiently wide, one may observe the characteristic extinctions of about 15° on oP.(001) and about 7° on $\infty\breve{P}\infty$.(010). Inclusions of albite are very abundant.

At Petalia, near Salem, the oligoclase is white, and, together with white quartz, forms a fine graphic pegmatite. The extinctions in relation to the edge oP. $\infty\breve{P}\infty$.(001)(010) are about 1° on oP.(001) and about 8° on $\infty\breve{P}\infty$. (010). On a plate parallel to $\infty\breve{P}\infty$.(010) the axes appear to the eye symmetrically placed with reference to the positive bisectrix c, which is nearly perpendicular to the plate. This oligoclase belongs to the second class of M. des Cloizeaux.[2]

It frequently encloses the little patches of microcline (Fig. 5)—

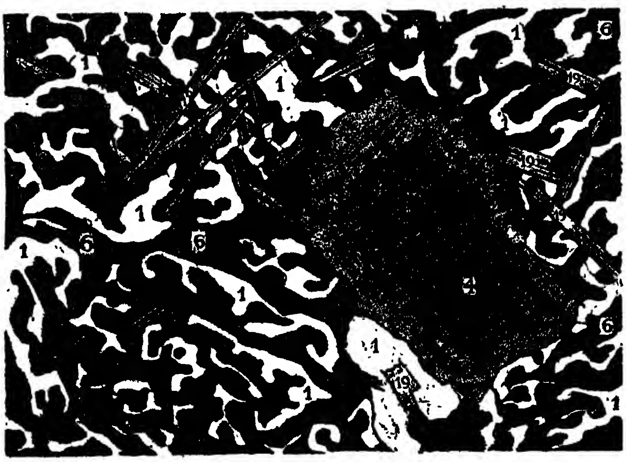

Fig. 5.—Pegmatite (Petalia).

1, Quartz. 4, Microcline.
6, Oligoclase. 19, White mica.

[1] 'Perunduré' (Keith Johnston's Royal Atlas) is about 45 miles south-west of Salem, in the Koimbatur district. It is spelled 'Peranduray' in the Preliminary Sketch of the Geology of India.—*F. R. M.*

[2] *Bull. Soc. Minér*, VII (1884), 249.

In the same rock (*gisement*) a fine white albite is found which cannot be distinguished by the naked eye from the preceding felspar. It occurs in large translucent plates, which are often cavernous, and, in such cases, filled with geodes of transparent quartz, and little hexagonal laminæ of white mica.

This mineralogical association is identical with that which occurs so frequently in the pegmatites of Norway, and notably at Gartå, near Arendal.[1] The hemitrope-bands on the albite-type are large and regular.

The extinction-angle in relation to the trace of this twinning is about 4° on oP.(001) and about 20° on ∞P̆∞.(010). The positive bisectrix $\mathfrak{c}$ is sensibly normal to ∞P̆∞.(010).

Numerous inclusions are observable in this felspar, comprising either opaque inclusions, generally distributed in the cleavage-fissures, or those of white micas. The latter occur in the form of very thin spangles disposed in three directions; some very small ones lie in the planes oP.(001) and ∞P̆∞.(010). The others, which are much larger, are parallel to the faces of a prism of 115°.

In microscopic sections cut parallel to oP.(001) these laminæ of mica may be seen in the form of long rods, intersecting at angles of 115° and 65°. The trace of the albite-twinning and the inclusions lying parallel to the trace of the cleavage ∞P̆∞.(010) [are parallel to] the bisectrix of the angle of 115°. The micaceous laminæ seem to mark the direction of a difficult cleavage. The angle given as 115° is a little variable, but is never as much as 117°. It therefore does not correspond to the prism ∞'P.∞P'.(110)(1̄10), which has an angle of 120° 47', but to a prism of the same zone. The white mica which accompanies this albite forms little greenish-yellow rosettes. The plane of the optic axes is perpendicular to ∞P̆∞.(010).

$$2E = \text{about } 72°.$$

De Bournon's collection includes a felspar which is opaque-white in mass, and remarkable for its pearly and silky lustre. When examined in microscopic sections, it is seen to possess the properties of normal orthoclase (*orthose non déformé*): the double refraction is more feeble than that of ordinary orthoclase. The cleavages oP.(001) and ∞P̆∞.(010) are very well marked, and their directions are often indicated by amorphous matter.

It has become very fragile, and merely by pressure with the finger breaks into little parallelopipeds. It contains opaque, extremely fine inclusions in considerable quantity.

We have observed an analogous mode of alteration in the felspar of a hornblendic gneiss forming the escarpments of Cape Palmas, at the mouth of the river Cavalla, on the coast of Maryland, to the south-east of Liberia (West Africa). This rock was collected, in 1885, by Dr. Jullien, who has been good enough to send it to us.

In its exterior aspect it bears much resemblance to the hornblendic gneisses of Ceylon. The milky-white felspar is disseminated in grains through the dark green hornblende. In some largely crystallized beds the former mineral predominates.

The microscope shows that the rock is composed of sphene, hornblende, oligoclase, orthoclase and quartz.

[1] A. Lacroix: "*Sur l'albite des pegmatites de Norvège*". Bull. Soc. Minér., IX (1886), p. 131.

The hornblende is strongly pleochroic, with:

$\mathfrak{c}$, dark sea-green,
$\mathfrak{b}$, yellowish green,
$\mathfrak{a}$, greenish-yellow,

and $\mathfrak{c} = \mathfrak{b} > \mathfrak{a}$.

The extinction angle on $\infty P \infty$.(010) is about 22°. The mineral is often fissured, and stained with yellowish ferruginous products.

The felspars, occurring in rounded grains, do not include any of the alteration-products habitual to such minerals: they are often much cracked, but the fragments are limpid, with the double refraction unchanged. The sinuous fissures which traverse the crystals, all remain dark in parallel polarized light. When the mineral is examined in ordinary light, a fibrous substance may be observed on both sides of the fissures, penetrating the mineral from thence, in the same way as the micaceous alteration-products of cordierite. In some cases the entire crystal is invaded by this substance, when it no longer has any action on polarized light. The composition of this isotropic substance is unknown to us (Fig. 6).

Fig. 6.—Alteration of felspars (Palmas).

To the left in polarized light; to the right in ordinary light (orthoclase, oligoclase, quartz and hornblende).

Besides these particular phenomena of alteration we may notice the occasional formation of secondary quartz, in little grains along the fissures just described.

It is in pegmatites similar to those which have been described above that the 'moonstone' variety of orthoclase occurs in Ceylon; it is so well known that further remarks are unnecessary.

All these felspars contain, in greater or less quantity, fusiform inclusions of unknown nature, which have been described as occurring in the felspars of the granulitic gneisses.

The collection in the Museum includes a fine specimen, from Perindoré, of a bright brown phlogopite, with the two axes nearly coincident.

Muscovite, also, is found, in large plates, penetrated by numerous patches of quartz, and forming a sort of pegmatite with the latter mineral.

Leschenault[1] notices the occurrence of beryl (aquamarine) in these rocks (Salem).[2]

Basic Gneisses.

(*a*). *Pyroxenic and hornblendic gneiss.*

These gneisses are especially well developed in the neighbourhood of Kandy. They are intercalated with granulitic gneisses and leptynites, into which they frequently pass by the addition of quartz and the disappearance of pyroxene.

Nevertheless, this rock is sufficiently constant in its composition, and forms one of the most characteristic types of that region: it greatly resembles the lower pyroxenic gneisses of Odegarden, in Norway.

These gneisses possess a high specific gravity and a dark colour.

Sometimes they are composed almost entirely of dark-coloured minerals (*éléments noirs*), which produce a stratiform structure; sometimes, on the other hand, the abundance of granular felspar masks the orientation of the ferruginous minerals.

Black hornblende, dark red almandine garnet, and a yellowish-white felspar may be distinguished with the naked eye. As at Bamle, in Norway, pyroxene can only be detected with the microscope: as at the same locality, also, the rock is but slightly coherent, and breaks easily, although its constituent minerals are unaltered. From this point of view, therefore, the rock bears some resemblance to the gneisses enclosed in volcanic rocks.

In addition to the preceding minerals the microscope discloses apatite, pyroxene, magnetite, and a little quartz.

Apatite is of frequent occurrence, in hexagonal prisms, some of which attain the size of half a millimetre The magnetite has no definite form. Quartz is present only as *quartz de corrosion*. The pyroxene is remarkable for its intense pleochroism. Sometimes in rounded grains, sometimes in irregular crystals elongated parallel to the edge of the zone $\infty \bar{P} \infty . \infty \breve{P} \infty .(100)(010)$, it possesses the cleavages $\infty P . \infty P .(110)(1\bar{1}0)$ which are sometimes very regular. In some cases there are also traces of cleavages parallel to $\infty \bar{P} \infty .$ (100) and $oP.(001)$, usually indicated by a considerable number of little rod-shaped, greatly elongated, opaque inclusions, which are only visible under high powers.

Besides these cleavages, there are numerous fissures which are filled by an isotropic ferruginous substance. Inclusions of magnetite and hornblende, and, very rarely, those of apatite, may also be observed.

The *pyroxene* is very transparent in microscopic sections; the polarization-tints are limpid.

The pleochroism is intense, very similar to that observable in hypersthene. We have—

$\mathfrak{c}$, Sea-green.
$\mathfrak{b}$, Bright pink.
$\mathfrak{a}$, Yellowish green.

The absorptions parallel to $\mathfrak{c}$ and to $\mathfrak{a}$ differ but little. It follows from this that

[1] *Op. cit.*

[2] Was M. Leschenault's beryl from Paddoor or Kangiam in Koimbatur? The latter town is about 20 miles south of Peranduray. See Manual of the Geology of India, III, 520.— *F. R. M.*

sections parallel to ∞P̄∞.(010), containing 𝔠 and 𝔞, are but slightly pleochroic, showing green tints.

The colour observed when the rays traversing the plate vibrate parallel to 𝔟 is nearly identical with that of the garnets, which are very abundant in the rock.

The maximum extinction on ∞P̄∞.(010) is about 45°.

$$\gamma - a = 0{\cdot}030.$$

The properties of the pyroxene nearly resemble those of the Arendal coccolite.

The *hornblende* is remarkable for its most intense pleochroism. It appears absolutely black to the naked eye, and occurs in crystals elongated in the direction of the zone ∞P̄∞.∞P̆∞.(100)(010), and sometimes attaining a size of 1·5 millimetres. The cleavages ∞P.∞P.(110)(1̄10) are very well marked, giving highly reflective surfaces.

The angle ∞P.∧∞P. = 124°15′

In microscopic sections these cleavages are very straight; the transversal fissures are much less frequent than in the pyroxenes. The pleochroism is as follows:—

𝔠, Brown-green; nearly black;
𝔟, Greenish brown; nearly black;
𝔞, Bright yellow,

with sensibly 𝔠 = 𝔟 > 𝔞.

The properties of the mineral are those of basaltic hornblende. The extinction angle on ∞P̆∞.(010) is very small (3° or 4°). The double refraction is strong, but difficult to measure, on account of the colour of the substance.

$$\gamma - a = \text{about } 0{\cdot}31.$$

Biotite is rare, and occurs in little aggregations around the magnetite.

The *garnet* is of the almandine variety: of a very dark red in mass, it is bright pink in microscopic sections.

The felspar occurs in rounded grains without definite form. It is always remarkably unaltered, and free from microscopic inclusions. To the naked eye it is yellowish, this colour being due to ferruginous products, which insinuate themselves between the crystals, or into the numerous fissures by which the latter are intersected.

They are purified, and rendered absolutely colourless, by treatment for some minutes with boiling hydrochloric acid: the portion attacked includes a little silica, alumina, ferric oxide, and traces of lime.

The optical properties are those of an andesine. As the size of the crystals is generally less than half a millimetre, it is impossible to determine the extinction upon the faces oP.(001) and ∞P̆∞.(010) with precision.

After breaking some of the crystals, and collecting the cleavage-plates thus obtained on a glass slide, I was unable, with certainty, to recognize traces of a second cleavage in any of them.

Assuming that such is in the direction of the most frequent fissures, the extinction-angle referred to their trace does not exceed 2°. In the zone of symmetry normal to ∞P̆∞.(010) the extinction-angles attain, but do not exceed, 20° on each side of the twinning plane on the albite-type.

Some crystals do not present a uniform extinction in parallel polarized light, but one which gradually alters in direction from the centre of the patch outwards (*rou-lante partant du centre de la plage*).

Twins on the albite- and pericline-types are frequent; the Baveno twinning is more uncommon.

The hemitropic bands of the two first types are fine and very well marked.

Quartz de corrosion is frequent enough in some specimens, and is entirely wanting in others.

It is difficult to determine, with precision, the order in which the constituents of the rock were formed. In fact, if we except the apatite, which is anterior to all the others, we may notice the hornblende sometimes included in the pyroxene, or the latter moulded on it, sometimes, on the other hand, the hornblende forms large patches around the other mineral. The relations of these bi-silicates to the oligoclase are not less difficult to determine, for in some cases they may be observed to localize themselves at the mutual contact of numerous felspathic grains and to surround them; in others to compose, with the felspars, pegmatoidal associations which suggest a simultaneous crystallization.

The same may be remarked concerning the garnet and magnetite, which are clearly of later origin than the coloured minerals. The felspar is always granular.

The rock just described is free from quartz; there are, however, varieties passing into leptynites. In such cases large quartzose patches are developed, which are moulded on all the other constituents of the rock.

(*b*). *Pyroxenic and hornblendic gneiss.*

The rocks belonging to this second type are characterized by the presence of a bright green pyroxene, which is almost colourless in thin plates, and of an equally bright green hornblende. Whilst the preceding rocks of the gneissose series correspond to the inferior gneisses of Norway, these, in their mineralogical composition approach the pyroxenic gneisses of Saxony and Brittany. Most of the varieties described in the sequel are found associated in a very small space in the E.-W. band of pyroxenic gneiss of Northern Finisterre. In India they present an external appearance which differs somewhat according to the locality. At Salem there are black, very compact rocks, sometimes extraordinarily rich in red almandine garnet, which occurs in grains of 2 millimetres diameter. At Perindoré, 10 miles (*4 lieues*)[1] distant, the garnet is isolated in crystals sometimes attaining the size of one's fist, which are surrounded by a sort of envelope of hornblende to be described further on. The rock in the latter locality is more largely crystallized than in the preceding one.

In Ceylon the rock is of a brighter colour. It is poor in, or free from garnet, and is composed of bright green pyroxene mixed with hornblende, together with hornblende in dark green crystals.

The same variety is found, but more rarely, at Salem.

These rocks are associated with true hornblendic gneisses free from pyroxene.

According to Leschenault's account, and to the labels attached to his specimens, the valley of Salem is formed of these gneisses, and with them are associated the anorthite-bearing rocks and cipolins described in the sequel. This fact completes the analogy with Finisterre pointed out above.

[1] *Sic*. Compare footnote on p. 16.—*F. R. M.*

They appear therefore to correspond to the upper part of the gneisses; to that horizon at which there are found in Brittany the pyroxenic gneisses which have formed the subject of a special chapter in this memoir. We shall see further on that this group of rocks is covered by true hornblendic or sericitic mica-schists equivalent to the French ζ^2.

In this series felspar is more rare, and it is only in exceptional instances that it constitutes one-fourth of the rock; frequently it is absent. Exception must, however, be made of some finely granular specimens, in which felspar is very abundant. The following minerals are noticeable: garnet, apatite, magnetite, pyroxene, hornblende, and sometimes quartz.

The magnetite often forms little stalactiform or dendritic masses.

The garnet is red almandine, dark-coloured in mass, pale pink in thin slices. Very frequently it contains numerous inclusions of rutile, in long needles similar to those that occur in the micas. These rutile-crystals cross each other at angles of 60° and 120° (Fig. 7). In the hexagonal sections of the garnets, these inclusions are arranged in parallelism to the sides of the hexagon.

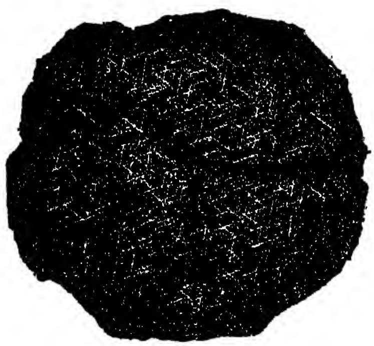

Fig. 7.—Garnet, with inclusions of rutile.

In studying these inclusions, one does not encounter the difficulties that are met with in the examination of those in the mica, for here, as their host remains dark between crossed nicols, there is nothing to interfere with the investigation of them. They possess a very strong double refraction, but, considering their very small thickness, they display vivid colours in polarized light. The sign is positive; the extinction always longitudinal. It is doubtless to the existence of similar inclusions that the phenomenon of asterism is due, which has been observed in a great number of Indian garnets.

There are, likewise, trains of liquid inclusions, which are only visible under high powers. They enclose a bubble, which is extremely small, but moves in an irregular way.

The garnet is often cracked, and filled with ferruginous products that are easily soluble in hydrochloric acid.

The *pyroxene* is bright green. It occurs in crystals attaining a length of several millimetres: sometimes it is distributed through the felspar in the form of crystallized powder (*poussières*).—Fig. 8.

Fig. 8.—Inclusions of pyroxene in felspar (Ceylon).
1, Quartz; 6, Oligoclase; 21, Hornblende.

The cleavages $\infty P . \infty P . (110)(1\bar{1}0)$ are well-marked: frequently there is also the cleavage $\infty \bar{P} \infty (100)$, which is very faint and generally interrupted. There is a feeble pleochroism, with—

$\mathfrak{c}$, sea-green;
$\mathfrak{b}$, very pale greenish yellow;
$\mathfrak{a}$, bright green;

$$\mathfrak{c} > \mathfrak{a} > \mathfrak{b}.$$

the difference of absorption between $\mathfrak{c}$ and $\mathfrak{a}$ is very slight.

The extinction on $\infty \breve{P} \infty . (010)$ is about 43°:

$$\gamma - \alpha = 0 \cdot 028$$

In some specimens of a bright colour, from Ceylon and Salem, there is a pyroxene in large patches which is absolutely colourless in microscopic sections. The cleavages $\infty P \infty P (110)(1\bar{1}0)$ are much sharper and closer together than in normal pyroxene. There are frequently numerous inclusions of magnetite distributed in parallelism to $\infty \bar{P} \infty . (100)$; but the cleavage of diallage does not exist. The mineral generally occurs alone, or accompanied by a little hornblende. All these pyroxenes are rich in inclusions of magnetite, hornblende due to uralitization, and in a mineral occurring in little rounded and elongated laminæ, more strongly refractive than pyroxene, and the principal axis of which coincides with the vertical axis of the pyroxene. The dimensions in which the mineral occurs are too small to allow of its determination.

$$\gamma - \alpha = 0 \cdot 025$$

The extinction angle is about 40.°

Three varieties of *hornblende* occur in these rocks accompanying, respectively, the pleochroic pyroxene (*a*), the colourless pyroxene (*b*), or else occurring alone (*c*).

a.—The pleochroic pyroxene is constantly associated with a *greenish brown hornblende*, which seems to be a product of uralitization. The latter mineral either surrounds the patches of pyroxene, with a more or less wide border, or else it occurs in the pyroxene cleavage $\infty \bar{P} \infty . (100)$.

This fact may be easily verified by the examination of sections normal to the vertical axis of the pyroxene, in which the diagonal of the angle of the cleavages ∞P.∞P.(110)(1̄10), (corresponding with the trace of ∞P̄∞.(100)) is marked by very thin little rods of hornblende, which are only the transverse sections of the plates of hornblende lying parallel to the orthodiagonal of the pyroxene. In sections of the prismatic zone the hornblende forms little narrow irregular plates, recognizable by their colour, their pleochroism, and their angle of extinction. The orientation of the hornblende is the same as that of the pyroxene which encloses it.

The transformation does not always take place in the same way: sometimes the hornblende presents irregular forms, and replaces the pyroxene in large patches, only rare 'islets' of the latter mineral remaining. It is generally in pyroxene crystals of small size that the mode of alteration just mentioned may be observed Extinction takes place at an angle of 18° from the vertical axis. The pleochroism is well marked:

𝔠, dark-green,
𝔟, brownish-green,
𝔞, greenish-yellow,
with 𝔠 = 𝔟 > 𝔞.

$\gamma - \alpha = 0{\cdot}027.$

The hornblende we are speaking of forms a sort of pegmatite with the quartz, either as a corona around the garnets, or in the intervals between the crystals of pyroxene.

b.—This variety of hornblende accompanies the colourless pyroxene of Kandy. It is found either in plates in crystallographic association with the pyroxene, or in large patches of 2 or 3 millimetres moulded on the latter mineral. The pleochroism is less marked than in the preceding varieties:

𝔠, green,
𝔟, yellowish-green,
𝔞, yellow,
with 𝔠 > 𝔟 > 𝔞.

The mineral is perfectly transparent and limpid in thin plates: it is also very poor in inclusions, and in this respect differs remarkably from the pyroxene which it accompanies. The cleavages ∞P.∞P.(110)(1̄10) (= about 124°) are sufficiently distinct.

The extinction-angle on ∞P̄∞.(010) is about 24°.

$\gamma - \alpha = 0{\cdot}028$

c.—The third variety of hornblende is distinguishable from the other two by its much brighter and more vivid pleochroism, with—

𝔠, bluish-green,
𝔟, yellowish-green,
𝔞, yellow,
and 𝔠 > 𝔟 > 𝔞.

Twinning on ∞P̄∞ (100), which has not been found in the other hornblendes of these rocks, is common enough in this variety.

The extinction on ∞P̄∞.(010) is 21°.

$\gamma - \alpha = 0{\cdot}024$

The felspar is oligoclase: the quartz is rich in inclusions, with moving bubbles, disposed in lines (*en files*) traversing many of the quartz-grains.

With regard to structure four varieties of the rock under discussion may be distinguished.

1st.—The rock is composed of the colourless pyroxene and the hornblende *h* alone, the latter being posterior to the former (Salem, Kandy). These rocks are of a bright-green, becoming yellow on the weathered portions. The colour of the rock becomes brighter as the proportion of hornblende diminishes.

Fig. 9.—Pegmatoidal pyroxene in oligoclase and quartz (Salem).

2nd.—To the constituents of the preceding variety, quartz and oligoclase are added, and the rock becomes freely granular: sometimes the grains are very fine and equal in size (a type similar to that of the pyroxenic gneiss of Loire-Inférieure); sometimes, on the contrary, the bisilicates occur in large elongated crystals [forming pegmatoidal associations with the white minerals[1]].—Fig. 9.

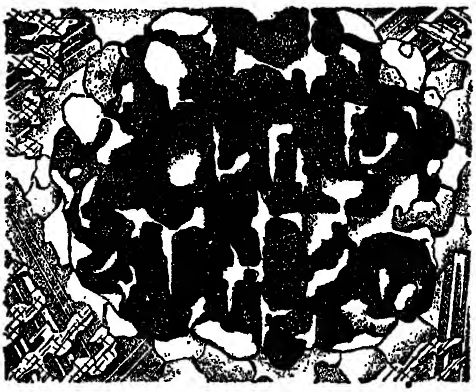

Fig. 10.—Pegmatoidal garnet in quartz (Ceylon).
At the corners of the figure, pegmatoidal pyroxene in oligoclase.

The garnet, when present, is always stalactiform, as shown in Fig. 10.

1. [By pegmatoidal association, I here mean the intimate penetration (intergrowth) of two minerals of simultaneous formation. One of them affects lace-like, crooked or cuneiform outlines, recalling those of quartz in graphic pegmatites. The pegmatoidal constituent is here hornblende, pyroxene, or garnet. The mineral forming the base of the pegmatite is felspar or quartz; sometimes both together.]

The hornblende belongs to the variety *b*, but possesses a slightly different pleochroism—

$\mathfrak{c}$, brownish-yellow,
$\mathfrak{b}$, bright-brownish yellow,
$\mathfrak{a}$, bright-yellow,

with $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$.

The angle of extinction is 15°, and the maximum double refraction :

$$\gamma - \alpha = 0{\cdot}028$$

It sometimes contains inclusions of zircon with pleochroic aureoles.

Quartz de corrosion is often abundant in the oligoclase. To this type a Salem rock ought to be annexed which is composed of greenish-black pyroxene, possessing on the prismatic cleavage planes the appearance of the schillerspar of the Harz. When examined in microscopic sections, this pyroxene is bright green: it is dotted with hornblende, and contains numerous cavities filled with quartz and oligoclase: it forms the skeleton of the rock. (Fig. 11.)

Fig. 11.—Pyroxenic gneiss (Salem).
20. Pyroxene with faculæ of hornblende (21) Pegmatoidal in oligoclase.

3rd.—This rock is very rich in garnets (Salem), which show out as red dots through the black mass: the specific gravity is very high.

The pleochroic pyroxene presenting transformations into hornblende, which has been described above, forms patches 2 centimetres long. Between the pyroxene and the garnet numerous grains of quartz occur, forming pegmatite with the hornblende, and separating the two principal minerals of the rock into little twisted fragments. We must also mention oligoclase here, which plays the same rôle.

A similar combination of pyroxene and of garnet, surrounded by the same sort of pegmatite, is met with in the pyroxenic gneisses (pyroxene-granulite) of Saxony, as well as in Finisterre, Auvergne, &c.

4th.—The fourth type is characterized by the hornblende *c*: it approaches the hornblendic gneisses, common in Auvergne, composed of hornblende and oligoclase. Sometimes the constituent minerals have nearly the same dimensions, and the rock is massive; sometimes, on the other hand, the hornblende occurs in large crystals elongated in the direction of the zone ∞P̄∞.∞P̆∞.(100)(010) which are orientated in accordance with, and determine, the schistose character of the rock. The greatest variety obtains in the relative proportions of these two minerals, in addition to which quartz is often present as an essential element, and sphene as an accessory.

The garnet is not distributed uniformly in the rock: it is concentrated in crystals, attaining the size of one's fist, surrounded by an envelope of green hornblende about 1 centimetre thick, and but slightly adherent to the enclosing rock. From the latter it is easy to detach the garnet and envelope, which then resemble a fruit. [Specimens of this kind seem to be abundant in the gneiss of Perindoré.]

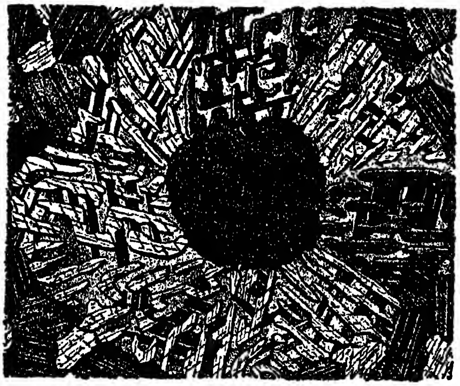

Fig. 12.—Garnet. with corona of pegmatoidal hornblende in oligoclase (Salem).

The hornblende of the corona seems brighter than that of the rock, an appearance which is due to the presence of white minerals (*éléments blancs*). Segments parallel to the apparent fibres (*fibrosité*) of the envelope show, in fact, that it is composed of sectors of hornblende elongated parallel to the zone ∞P̄∞.∞P̆∞.(100)(010), and the vertical axis of which is normal to the surface of the garnet. These hornblende crystals are pitted with cavities, and resemble a sort of lace-work which is filled up by oligoclase and quartz (Fig. 12).

The phenomenon presented here is analogous to that which has been described under type 3, but much more regular. When the slice is revolved between crossed nicols, the different sectors become successively light and dark. The diversely orientated patches of hornblende in these sectors have crystallized simultaneously, for one may often notice a single felspathic patch in pegmatoidal association with different hornblendic elements.

The following table gives, in one view, the properties of the pyroxenes, and hornblendes associated with them, in the rocks of Ceylon and Salem. It will be seen that the different hornblendes fairly well characterize, respectively, the varieties of rock that we have established. In the same way as in the Norwegian rocks, the strongly pleochroic pyroxenes are accompanied by intensely-coloured brown hornblende, while the rocks containing scapolite and basic felspars include grass-green hornblende, showing very vivid pleochroism. The pyroxenes with very feeble, or no pleochroism, on the contrary, are associated with the most ordinary varieties of hornblende. The variations in composition of these different hornblendes will be discussed in a future memoir.

Rocks.	Pyroxenes.						Hornblendes.					
	Extinction.	c	b	a	Absorption.	$\gamma - \alpha$	Extinction	c	b	a	Absorption.	$\gamma - \alpha$
Pyroxenic gneiss *a*	45°	Sea-green.	Bright pink.	Yellowish green.	c = a > b	0·030	3° to 4°	Dark brown-green.	Dark-greenish brown.	Bright yellow.	c = b > a	0·031
Ditto *b* 1st variety	43°	Pale sea-green.	Greenish yellow.	Sea-green	c > a > b	0·028	18°	Dark green.	Brownish green.	Greenish yellow.	c = b > a	0·027
Ditto *b* 2nd "	40°	0	0	0	...	0·029	24°	Green	Yellowish green.	Yellow	c > b > a	0·028
Ditto *b* 3rd "	...	...	...	...	..	..	15°	Brownish yellow.	Bright brown-yellow.	Bright yellow.	c > b > a	0·028
Ditto *b* 4th "	...	...	...	..	...	..	21°	Bluish green.	Yellowish green.	Bright yellow.	c > b > a	0·024
Anorthite- and Scapolite-bearing rock.	40°	Pale green.	Colourless	Colourless	c > b = a	0·027	12°	Dark grass-green.	Dull yellow-green.	Bright brown-yellow.	b > c > a	0·024

To the basic series may be referred two exceptional specimens which cannot be included in any of the preceding groups. They are both from the neighbourhood of Salem. In the first, hornblende, felspar, and garnet may be distinguished with the naked eye. Under the microscope we may observe that the hornblende, of a very bright bluish green, forms agglomerations of little crystals, often due entirely to the alteration of crystals of pyroxene.

In this confused aggregation of hornblende, bright pink garnet, rutile, and some grains of quartz are disseminated. The rock also includes a triclinic felspar, in large patches, without definite form, filled with extremely numerous crystals of zoisite measuring about half a millimetre in length, and 0·05 to 0·10^{mm} across. They are very well formed, and show numerous transversal fissures. All their optical properties conform to those of zoisite.

They show out vividly, by their refraction, upon the absolutely unaltered felspar which encloses them. Very often they are disposed in geodes filled by the felspar after their crystallization.

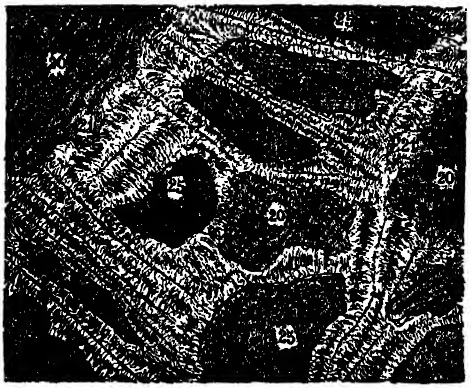

Fig. 13.
20, Pyroxene; 25, Garnet.

The other specimen is composed of pyroxene, garnet and hornblende. The first two minerals occur in large crystals on which is moulded the bright green hornblende, which is disposed in radiate coronæ (Fig. 13).

This hornblende recalls, by its mode of occurrence, the radiate hornblende surrounding the olivine-crystals of Loire-Inférieure and Norway.

Anorthite-gneiss.

These rocks are found at Salem, and, more rarely, in the neighbourhood of Kandy, intercalated with the gneisses previously described. Independently of their mineralogical interest, they are most interesting from an historical point of view; for some of the specimens that have passed through my hands are the originals utilized by de Bournon for his memoir on corundum[1], and now preserved, with his

[1] "*Description of the Corundum stone and its varieties*,"—Phil. Trans., London, 1802. [On the labels of several specimens in Leschenault's collection, more precise reference is made to the localities,—"34 miles *(14 lieues)* S.S.W. from Salem, and 17 miles *(7 lieues)* E. from Kandy."]

collection, in the Collège de France. They are white, yellow, greenish, or pink, saccharoid rocks, sometimes nearly compact, sometimes formed of grains of anorthite attaining a size of 0·5 to 1 millimetre. Disseminated in the anorthite there may be distinguished, with the naked eye, *black hornblende, garnet,* a new mineral to which I have given the name of *fouqueite,* and large crystals of *corundum.* Petrographical examination further discloses *scapolite, pyroxene,* and *epidote.*

When the rock is fine-grained, it possesses a high degree of tenacity; but when composed of large crystals it is easily disintegrated, and is reduced to sand beneath the hammer.

The different minerals, just enumerated, are not equally distributed through the rock: they form layers (*lits*), generally sufficiently distinct, and giving rise to four principal types:—

1st, Rock composed of anorhite alone.
2nd, " " " " and garnet.
3rd, " " " " and scapolite.
4th, " " " " and fouqueite, hornblende, and pyroxene.

The rocks belonging to the 1st and 3rd types are white, those of the 2nd being white or bright pink. Those of the 4th type are sometimes yellow, sometimes speckled with black in accordance with the greater or less abundance of the ferruginous bisilicates.

We may remark, once for all, that these different varieties have no geological importance, and are only accidental ones, which are sometimes found together in the same specimen of rock measuring but a few decimetres. We shall take no further notice of them in the sequel, which will be devoted to the study, in succession, of all the above constituents of a unique rock.

In writing on the gangue of the Carnatic corundum[1], de Bournon, under the name of "Matrix of corundum," gave the first description of *anorthite.* Subsequently in the description of his collection[2], now preserved in the Collège de France, he proposed the name of "*indianite*" for the new mineral. If the law of priority were followed with reference to mineralogical nomenclature, this name should be preferred to that of anorthite, which was proposed by G. Rose in 1823.[3]

De Bournon's description is excellent for the time, putting aside the question of crystalline form. He suggested (although doubtfully) the hypothesis of a rhombohedral crystallization: it was subsequent to this that Brooke and Rose assigned to anorthite a triclinic form.

The *anorthite* constitutes nine tenths of the rock, which occurs in granular masses, the individual grains in which measure about half a millimetre in their longest direction. Usually white, it sometimes becomes pink or greenish owing to the presence of fine crystals of garnet, hornblende, &c.

The felspar is fusible before the blow-pipe to a white glass, and is easily attacked by hydrochloric acid, although preserving its form; it possesses all the properties of typical anorthite.

Microscopic sections show the anorthite in the form of rounded grains, the

[1] "*Description of the Corundum stone and its varieties.*"—Phil. Trans., London, 1802, 233.
[2] Catalogue de la collection Minér, particulirére du roi, Paris, 1817.
[3] Gilbert: Ann. LXXIII (1823), 197.

contact-lines between which are often rectilinear. Twinning occurs on the Carlsbad-, albite-, and pericline-types, but untwinned crystals are not uncommon. The form of the hemitrope-plates on the albite-type is most varied: sometimes a patch is composed of two or three large bands; sometimes, on the other hand, there is a very large number of more or less narrow ones, but always very regular and not presenting any trace of dynamic phenomena.

Very often Carlsbad-twinning is superposed on that of albite.

The hemitrope-lamellæ on the pericline-type are only observed, as a rule, in the midst of some of the bands belonging to the albite-twinning.

Extinctions in parallel light take place in the zone perpendicular to $\infty \breve{P} \infty$. (010) at very large angles—as much as 45°.

Extinction on a plate parallel to the principal cleavage oP.(001) occurs at 39° from the edge oP:$\infty \breve{P} \infty$.(001)(010). Owing to the small thickness of such plates I have not been able to obtain any parallel to the second cleavage $\infty \breve{P} \infty$.(010).

During the examination of a great number of sections, I succeeded in finding some sufficiently nearly perpendicular to the three principal axes of the ellipsoid of the indices, and in measuring their differences by means of Michel Lévy's '*comparateur*' we have—

$$\gamma - \alpha = 0{\cdot}013.$$
$$\gamma - \beta = 0{\cdot}007.$$
$$\beta - \alpha = 0{\cdot}008.$$

The bisectrix is negative, α. In the section perpendicular to the bisectrix, the trace of the plane of the optic axes makes an angle of 41° with the trace of the twinning on the albite-type.

$$2E = \text{about } 130°$$

Several analyses have been published of this anorthite by different chemists—

	Chenevix.[1]	Laugier.[2]		Brush.[3]
Silica	42·5	42·00	43·0	42·09
Alumina	37·5	34·00	34·5 }	38·89
Ferric oxide	3·0	3·20	1·0 }	
Lime	15·0	15·00	15·6	15·78
Soda	...	3·35	2·6 }	4·08
Potash	...	...	... }	
Water	...	1·00	1·0	
	98·0	98·55	97·7	100·84

All of these analyses have been certainly made upon imperfectly purified material. In order to obtain material absolutely free from foreign minerals, I took a specimen from which several plates were cut in different directions: they enclosed no scapolite, but only corundum, pyroxene, hornblende, and fouqueite in small quantities.

After treatment, several times, with a solution of tungstoborate of cadmium, these different minerals were eliminated. The purity of the material was verified under the

[1] Phil. Trans., 1802, 334.
[2] Mémoires du Muséum d'Hist. Nat., vii, 341.
[3] Am. Jour. Sci., 2nd Ser., viii, 391.

microscope. Traces of calcite were got rid of by a rapid treatment with acetic acid.

Thus purified, the anorthite is in the form of small, absolutely transparent flakes. Their specific gravity is 2·71, and their composition :

Silica	42·80
Alumina	38·06
Lime	19·31
Soda	traces
	100·17

which is a close approximation to the oxygen ratio 1 : 3 : 4. This Salem felspar is therefore typical anorthite.

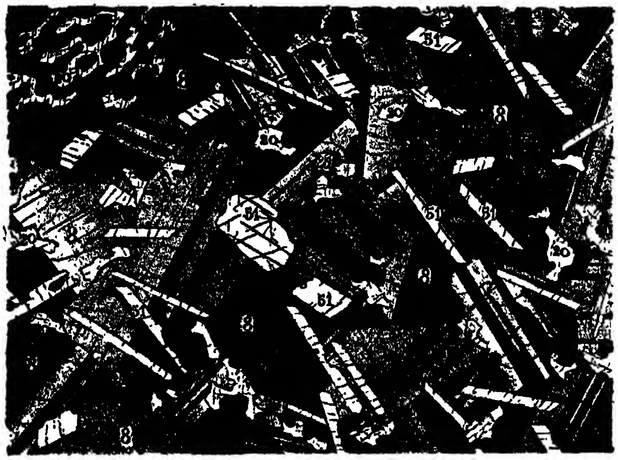

Fig. 14.—Anorthite-and fouquéite-gneiss (Salem).
8, Anorthite; 20, Pyroxene; 25, Garnet; 51, Fouquéite.

The *fouquéite* is of a fine yellow citron-colour : when it alone is associated with anorthite, it colours the rock yellow.

The mineral occurs in elongated crystals, measuring about 0·5 to 1 millimetre, rarely showing edges or sharp angles : generally the crystals are corroded and their forms rounded. There is a well-marked cleavage oblique to the elongation, and making with that direction, in the zone of elongation, an angle of 90° to 108° according to the section (Fig. 14).

The mineral is monoclinic. We may observe sections with symmetric extinctions, in which the cleavage is transverse; others, on the contrary, show oblique extinctions, the latter being those in which the cleavage makes an angle of 108° with the elongation.

The plane of the optic axes is parallel to the principal cleavage, which we take for the base oP (001) : it was easy to verify this with the purified material used for analysis.

The faces at 108°, noticed above, are sections parallel to the plane of symmetry ∞P∞ (010).

The divergence of the axes is very great, the angle 2 V being near 90°. However, by using an objective of wide angle, the acute angle of the optic axes may be observed to contain 𝔠, coinciding with the orthodiagonal. The optic sign of the mineral is therefore positive.

The sections being very thin and the mineral possessing a medium double refraction,

$$\gamma - \alpha = 0{\cdot}020,$$

I was unable to ascertain if there is crossed dispersion at each side of the bisectrix. A slight ordinary dispersion may be observed with $\rho < v$.

The mineral, which is nearly colourless in microscopic sections, possesses an extremely feeble pleochroism, with—

𝔠, colourless.
𝔟, very pale yellow.
𝔞, colourless.

Polysynthetic twins occur, with ∞P̄∞.(100) for the composition face.

The greatest care was taken in obtaining two grammes of pure material. Most of the anorthite and hornblende was separated by means of Daniel Klein's solution; prolonged boiling in hydrochloric acid, followed by rapid washing with hydrofluoric acid, removed the last traces of anorthite.

The substance, thus treated, is in the form of a crystalline powder, composed equally of colourless grains and of those having a fine yellow citron-colour. In order to insure the absence of all foreign matter, a very large number of grains were examined in convergent polarized light: they were truly parallel to the plane of the optic axes. A long and troublesome sorting, by hand, resulted in the separation of a small quantity of each substance.

The mineral is infusible before the blow-pipe: heated in a Forquignon and Leclerc's furnace, with the tromp, it fuses with difficulty to a transparent greenish glass, having a specific gravity of 2·76, and gelatinizing easily with hydrochloric acid, which does not attack the mineral before fusion.

On analysis, by Deville's method, the following results were obtained:—

	white.	(b) yellow.	Oxygen Ratio. (a)		Oxygen Ratio. (b)	
Silica	38·6	38·3		20·6		20·4
Alumina	32·5	31·9		15·0		14·8
Ferrous oxide	1·9	4·4	0·4	7·2	1·0	7·9
Lime	23·9	23·5	6·8		6·9	
Loss on ignition	2·7	2·7				
	99·6	100·8				
Specific gravity	3·24	3·31				

The oxygen ratio for (*a*) is 1 : 2·1 :: 2·9, and for (*b*) 1 : 1·9 :: 2·6. These ratios are near those given by the analyses of *zoisite.*

The optical properties, however, do not leave any doubt as to the difference between the mineral under discussion and zoisite. They present, therefore, a case of dimorphism, and I propose, for the Salem mineral, the name of *fouquéite.*

The *wernerite* occurs in transparent rounded grains measuring about half a millimetre. The cleavages ∞P.∞P.(110)($\bar{1}$10) are generally indistinct, but sections parallel to oP.(001) may be found in which the cleavages are seen to intersect at angles of 90°. The double refraction is uniaxial and negative:

$$\omega - \epsilon = 0{\cdot}027.$$

Like all the constituents of this anorthite-rock, the wernerite is very fresh and free from alteration.

The *garnet* occurs in crystals, measuring about a millimetre, of a slightly yellowish pink colour. In microscopic sections the pink tint is scarcely perceptible. The crystals are sometimes contorted, and frequently cracked.

The *pyroxene* is but slightly pleochroic, in sea-green tints, with the greatest absorption parallel to 𝔠. Extinction on ∞P̄∞.(010) takes place at about 40° from trace of the principal cleavage.

The maximum double refraction is:

$$\gamma - a = 0{\cdot}027.$$

The *hornblende*, when in thick crystals, is very dark green, nearly black, while microscopic sections show a fine green colour. The pleochroism is intense, with—

𝔠, dark blue-green,
𝔟, dull yellow-green,
𝔞, bright brownish yellow,
and 𝔟>𝔠>𝔞.

$$\gamma - a = 0{\cdot}024.$$

The maximum extinction on ∞P̄∞.(010) is [18° to 20°].

The cleavages ∞P.∞P.(110)($\bar{1}$10) are very fine; the fissures very numerous. Like the pyroxene, this hornblende is free from inclusions and perfectly limpid.

The *epidote* is rarely disseminated through the rock, generally forming granular masses composed of little rounded, greenish-yellow, transparent crystals, mixed with hornblende and a little anorthite. To the naked eye these epidotic concentrations resemble certain olivine-bearing nodules sometimes found amongst the ejected products of Somma.

In microscopic sections it may be observed that these crystalline grains, which rarely exceed half a millimetre, are monoclinic, and possess the properties of epidote. Colourless or slightly yellow, in the latter case they show slight pleochroism, the yellow tint corresponding to rays vibrating parallel to 𝔞.

The maximum extinction, referred to the trace of the principal cleavage oP.(001) in the zone oP.∞P̄∞.(001)(010) is about 30°. The cleavage ∞P̄∞.(100) is very faint.

Twinning on ∞P̄∞.(100), so common in large crystals of epidote, is entirely wanting. The bisectrix is negative (𝔞). This epidote is remarkable from the fact of its being an original constituent of the rock: anterior to all the minerals that accompany it, the anorthite and hornblende are moulded on it. It is clearly differentiated from the fouquéite, with which I have never met it in the same specimen.

In a specimen obtained 17 miles (*7 lieues*) east of Kandy, *sphene* is very abundant in the spindle-shaped form habitual to it in the gneissose rocks: it is often enclosed by the garnet. To the preceding constituent we should add *calcite*, as a secondary mineral, which, however, occurs but rarely in these rocks, which are remarkable for their unaltered condition.

The structure of these rocks is uniformly granular (Fig. 59). All the constituents have about the same dimensions, and crystallized at nearly the same time.

These different minerals are generally found at the junction of several anorthite crystals, and, more rarely, are enclosed in the midst of a patch of felspar. In some cases it seems that the pyroxene, hornblende and scapolite have been moulded on the felspathic grains, and are consequently posterior to them; in others, on the contrary, the crystallization of the anorthite is clearly seen to have been accompanied by an attraction of the neighbouring crystalline grains, which have grouped themselves around the felspar.

Sphene has only been found in one rock, accompanying garnet, and enclosed by the latter; it seems to be the first-formed constituent of the rock. It is also abundant as inclusions in the anorthite, and bordering the crystals of the latter.

The *hornblende* and *pyroxene* are contemporary: very often the pyroxene forms a sort of envelope to the hornblende, but in other cases the reverse is true.

The *garnet* and *fouquéite* are, in part, of later origin than the two preceding minerals.

Finally, as has been said above, the *epidote* is enclosed by the hornblende, on to the large patches of which the anorthite is moulded.

The anorthite rocks, just described, seem to be the highly felspathic equivalents of the pyroxenic gneisses of Brittany, in the upper series of gneisses (*l'étage supérieur des gneiss*); but they present mineralogical peculiarities which entitle them to a separate place in this series.

Wollastonite- and scapolite-bearing rock.

The rock to be described in the following section is one of the most interesting that we have had under review. It is, in fact, composed of grossular garnet, diopside, pyroxene, wollastonite, scapolite, and a mineral that we have not been able to refer with certainty to any known species.

The rock comes from the neighbourhood of Salem, and is intimately associated with the anorthite-rocks just described.

It is of a bright cinnamon red colour, the garnet predominating. One may further distinguish, however, with the naked eye, a white, pearly, easily cleavable mineral, and bright green pyroxene. Microscopic examination discloses, in addition, the minerals enumerated above.

The garnet is slightly-reddish cinnamon-yellow, colourless in thin slices, and perfectly free from inclusions. It occurs in rounded grains without definite form. It fuses easily, before the blow-pipe, to a dark brownish green, non-magnetic bead. The powder is white, and is attacked with difficulty by hydrochloric acid.

It is a lime-garnet, which should be referred to the variety of grossular known as essonite. The specific gravity is 3·52.

The *pyroxene*, which is bright grayish green to the naked eye, is absolutely colourless in sections $\frac{1}{100}$ of a millimetre in thickness. No sensible pleochroism is visible in a thick cleavage-plate. The mineral does not occur in any definite form. The cleavages $\infty P \infty P.(110)(1\bar{1}0)$ are well-marked, but very coarse. No trace is visible of the cleavages $\infty \bar{P} \infty (100)$ and $oP.(001)$. On the face $\infty \breve{P} \infty$ (010)*c* makes an angle of about 41° with the trace of the prismatic cleavage. There is elongation in the direction of the zone ∞P̄∞.∞P̄∞.(100)(010).

The *wollastonite* is indistinguishable, to the naked eye, from the scapolite which accompanies it. The white constituents of the rock are easily cleavable, with a pearly lustre upon the cleavage-planes. The wollastonite dissolves more easily than the scapolite in hydrochloric acid. Before the blow-pipe both melt, with intumescence, to an opaque, white, vesicular glass. The crystals are elongated in the direction of the zone oP.∞P̄∞.(001)(100). The cleavage oP.(001) is very easy, fine, and rectilinear, contrasting with the coarse cleavage of the associated pyroxene. Twins on oP.(001), formed of two individuals, were observed several times.

The plane of the optic axes is parallel to ∞P̄∞(010) and consequently transversal to the elongation oP.∞P̄∞.(001)(100); sections of the zone of elongation are sometimes positive, sometimes negative, but the former predominate.

The bisectrix is negative α and perpendicular to a face of the zone oP.∞P̄∞ (001)(100).

$$2E = \text{about } 40^\circ.$$

The maximum double refraction is—

$$\gamma - \alpha = 0{\cdot}015.$$

The mean index of refraction is much lower (1·63) than that of pyroxene, so that the latter appears in relief on the wollastonite. The polarization tints are bright, and uniform in any one crystal.

The wollastonite is often cracked, with secondary calcite along the cleavages and in the fissures.

The *scapolite* occurs, both in large crystals, elongated in the direction of the zone ∞P.∞P.(110)(1$\bar{1}$0) and attaining a size of two millimetres, and in rounded grains.

The cleavages ∞P.(110) are not always well-marked; by considerably lowering the condenser of the microscope, however, they can be distinguished, especially upon the margins. Some sections parallel to oP.(001) display these cleavages intersecting at an angle of 90°. The double refraction is negative and strong.

$$\omega - \varepsilon = 0{\cdot}04.$$

This scapolite is especially rich in lime, and belongs to the meionite group; it is the most strongly doubly refractive that we have hitherto met with in any rock. It is less refractive than the wollastonite, and appears depressed beside it.

The pyroxene and wollastonite sometimes enclose garnets, but more commonly the latter are moulded on them; the scapolite seems of later origin (Plate I, Fig. 4).

I have found a few crystals of anorthite enclosed in the garnet. The rock contains another mineral, in some abundance, which resembles a felspar, but I cannot say with certainty that it is such. Inclusions of calcite are always very abundant in the felspathic mineral, either along the cleavage-planes, or forming numerous little faculæ.

At Sankeridurg, about 20 miles S.-W. from Salem, there are found, interstratified with the gneiss, beds of brownish-yellow garnet, with greasy lustre, dotted over with white saccharoid crystals.

Under the microscope minute crystals of wollastonite, pyroxene and calcite may be distinguished, disseminated through the garnet in the form of a veritable powder. They have no geometrical contours.

At Ouraka, near Kandy, a garnetiferous rock is met with, which greatly resembles that of Salem: it is rich in calcite, and likewise encloses granules of quartz.

Cipolins.

Cipolins are not uncommonly intercalated with the gneisses of Ceylon. The collections of de Bournon and Leschenault include numerous specimens, mostly collected 17 miles (7 *lieues*) east of Kandy, from the acid gneisses described above.

They are mainly composed of dolomite, the patches of this mineral measuring, on an average, 2 millimetres in the longest direction. Occasionally, however, the faces attain as much as 2 or 3 centimetres

Calcite is of frequent occurrence, and principally in the largely crystallized varieties, which are sometimes composed of it alone.

The minerals that are met with are always visible to the naked eye: these include apatite, phlogopite, spinel and pyrrhotine. They are very irregularly distributed through the rock, and are sometimes found alone, in other cases together. At times they are agglomerated, and form but slightly coherent nodules.

The fundamental constituent of the rock is dolomite, with which calcite is associated. Their mode of association is worthy of special mention.

When the rock is treated with cold hydrochloric acid, a lively effervescence is produced; the residue is composed of little transparent primitive rhombohedrons of dolomite, and of the different minerals just enumerated.

The soluble part, corresponding to the calcite, has the following composition:—

Calcium carbonate	91·10
Magnesium carbonate	8·89
	99·99

The crystals of dolomite were collected, washed, and analyzed with the following result:—

[Calcium carbonate	58·39
Magnesium carbonate	41·61
	100·00]

approximating to the formula $CaCO_3.MgCO_3$. Their specific gravity is 2·89. R/R. = 106° 18′.

Numerous writers have endeavoured to establish a microscopic means of distinguishing dolomite from calcite. Inostranzeff[1] relies on the frequency of twins on $-\frac{1}{2}$R.(01$\bar{1}$2) in calcite; Dœlter[2] on the greater resistance of dolomite to the action of weak acids; Lagorio and also Bonney[3] lay stress on the tendency of dolomite to assume rhombohedral forms R.(10$\bar{1}$1); Renard,[4] in his memoir on

[1] Tschermak, Mineral. Petr. Mittheil., 1873, 166.
[2] Verhandl. der k. k. geol. Reichsanstalt, 1875, 45.
[3] Quart. Jour. Geol. Soc., 1879, 167.
[4] Bull. Acad. Royale de Belgique, xI, vii, No. 5, 1879.

the Devonian dolomites of Belgium, has given a good *résumé* of the question, insisting on the last of these characters, and remarking that the calcite often serves to cement the rhombohedrons of dolomite.

In the rocks that we are now describing, the *dolomite* forms large patches without definite form, the mutual contact lines of which are not rectilinear. The cleavage R.(10$\bar{1}$1) is very well marked. Twins on $-\frac{1}{2}$R.(01$\bar{1}$2) are very frequent and often give rise to large hemitrope bands.

The *calcite* plays but a secondary part in the rock. It does not form a cement to the dolomite, but occurs in the latter in the shape of rounded grains, plates, or large patches denticulated into picturesque forms, or, again, in little delicate palm-like shapes, imitating all the forms that may be noticed in the *quartz de corrosion* in felspars. (Fig. 15.)

Fig. 15.—Cipolin, containing chondrodite (Ceylon).
49, Calcite ; 49′, Dolomite ; 53, Chondrodite.

It would appear that the calcite may be a secondary product, formed after the definitive consolidation of the rock. This hypothesis is confirmed by the fact, described further on, of the crystallization of the calcite in the midst of, or replacing, altered chondrodite.

Under the microscope the calcite may be distinguished from the dolomite by its greater limpidity, and the rarity of cleavage-planes; twins on $-\frac{1}{2}$R.(011$\bar{2}$) occur, but less commonly than in the dolomite. The action of hydrochloric acid on microscopic sections confirms the results obtained by optical examination.

The *apatite* is met with, both completely isolated, and in the midst of nodules of phlogopite.

The crystals are hexagonal prisms, very much elongated in the direction of the vertical axis. They are never well-formed, but always irregular, as if corroded. They have a brilliant lustre, and possess all the properties of normal apatite. The colour is a fine, bright-blue, somewhat verging towards green, and recalling the variety found at Arendal, which has received the name of moroxite.

Although colourless in microscopic sections, the crystals are intensely pleochroic in plates of a millimetre in thickness. We have:

o colourless.
e blue.

The *spinel* occurs in octahedrons O.(111) the angles and edges of which are often rounded: traces of the rhombic dodecahedron ∞O.(110) may sometimes be noticed. The most usual colour, in the specimens that I have examined, is a slightly wine-tinted, violet pink.

The crystals of spinel, found so numerously in the sands of the rivers flowing from the interior of Ceylon, are probably derived from the rocks in question.

The *phlogopite* has a fine golden yellow colour. It occurs both in fairly-well formed little crystals measuring a millimetre, and in plates attaining as much as 3 centimetres in the longest direction. Such crystals are curved. They often enclose grains of calcite in an irregular way, simulating, to the naked eye, a coarse pegmatite. The thickness is sometimes as much as 3 millimetres, the crystals under such circumstances being perfectly transparent, so that the containing rock can be seen through them in a direction perpendicular to the cleavage oP.(001).

The only well-formed crystals are the small ones, disseminated through the varieties of rock that are poor in minerals. These are little hexagonal prisms ∞P.∞P̆∞.oP.+P.(110)(010)(001)($\bar{1}1\bar{1}$) measuring about 1·5 millimetres in length by 1 in breadth. The faces oP.(001) and ∞P̆∞.(010) are well formed, while ∞P.(110) are rounded: the faces +P.($\bar{1}11$) are striated in steps parallel to their intersection with oP.(001). Only the angle oP./∞P̆∞.(= 90°) is measurable with the goniometer.

A cleavage-plate oP.(001) presents the form of a regular hexagon: the traces of ∞P̆∞. are very straight. The angle oP./∞P. is sharp, while the angles ∞P./∞P (110)/(1$\bar{1}$0) are always rounded.

The mica is colourless in thin plates, but of a fine yellow colour, and strongly pleochroic, in plates of a millimetre. In this respect two varieties may be distinguished, one a bright golden yellow, the other inclining towards reddish brown. The pleochroism of the latter is of the same kind, but with darker tints. Between the above two extremes every gradation may be observed:

𝔠, bright yellow,
𝔟, reddish brown-yellow,
𝔞, colourless,

with 𝔟>𝔠>𝔞.

The angle 2V is much the greater in the dark variety, as we shall see further on; in this variety, also, the absorption parallel to 𝔟 and to 𝔠 differs more than in the bright-tinted kind.

The plane of the optic axes is parallel to ∞P̆∞.(010).

The bisectrix is negative, a, and sensibly normal to oP.(001).

The divergence of the axes is very variable:

$2\,E = 15^\circ$, in the bright coloured variety.
„ $= 35^\circ$, „ dark „

The dispersion is scarcely sensible, with $\rho < v$. It may be noticed that the divergence of the axes increases with the greater amount of iron in the dark varieties.

Some crystals contain numerous inclusions of rutile, analogous to those that I have described as occurring in the phlogopites of Templeton, in Canada.[1] They are in the form of colourless needles (sagenite) with irregular outlines, presenting twins on $\frac{1}{2}$P. (112). The crystals are not arranged in parallelism to the faces ∞P ∞P̶∞ (110)(010) of their host, as is usually the case, but normally to them, and consequently parallel to the rays of the pressure-figures *(les plans de choc; Druckfiguren of Reusch)* that are obtained by pressing a cleavage plate of magnesian mica with a blunt point (Fig. 16)—

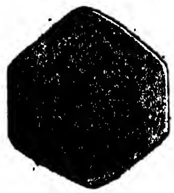

Fig. 16.—Inclusions of rutile in phlogopite (Ceylon).

Although sections of the mica parallel to oP.(001) act in a very marked way on polarized light, it is possible to study the optical properties of the rutile inclusions. The crystals lying normally to ∞P̶∞ (010) have their principal indices in parallelism with those of the plate of mica; the two minerals therefore become light or dark simultaneously. But the case is different for the crystals normal to ∞P.(110). When the mica is in the position of extinction, it may be seen that they act on polarized light in a sufficiently vivid way, and that the sign of the zone of elongation is positive. The analogy in properties that the Ceylon crystals present to those of Templeton, that I have been able to isolate and determine chemically, leaves no doubt as to the nature of the former.

The crystals of *chondrodite* scarcely exceed 2 millimetres, and are always rounded, without distinct form. The colour varies in different specimens from bright green-yellow to brown-yellow. Frequently the same crystal presents the two colours, one at each extremity. In spite of this, the mineral is colourless in microscopic sections and consequently non-pleochroic. When grains of it, crushed between two plates of glass, are examined under the microscope, it is found that the colour is due to ferruginous infiltrations, which, on account of their slight thickness, disappear, for the most part, when the mineral is cut into microscopic sections.

The study of the optical properties of this mineral is rendered difficult by the absence of cleavage, pleochroism, twins, and external form. I have been able to determine only that there is a positive acute bisectrix, at each side of which the axes are very divergent; the angle in air exceeds 120°, but did not admit of exact

[1] Bull. Soc. Min., viii (1885), 99.

measurement. Nevertheless, the chemical properties, and comparison with numerous authentic specimens of chondrodite, leave no doubt concerning the accuracy of our determination.

Although rarely transformed completely, the chondrodite presents numerous and interesting alterations. It is often broken, and in each of the fissures there has been produced a thin vein of chrysotile, which sometimes entirely surrounds the crystal and separates it from the enveloping calcite. More frequently there is a zone, of about a tenth of a millimetre, around the crystal, in which the chondrodite is reduced to fine débris that remains orientated in the same way as the crystal from which it is derived, but cemented by the calcite: the latter often occurs in extremely fine particles.

In such cases, between this zone of partial alteration and the dolomite in large plates, there is a 'muff' of calcite granules placed side by side tangentially to the crystal of chondrodite, in such a way that their principal axes are normal to the surface of the crystalline grains that they surround. (Fig. 15.)

The *pyrrhotine* occurs in the form of little hexagonal prisms $\infty P.oP.(10\bar{1}0)(0001)$. They did not escape de Bournon,[1] who noticed their magnetism, and regarded them as a 'martial pyrites' containing less [sulphur] than usual.

At Cornigal, about 40 miles (16 *lieues*) N.-W. from Colombo,[2] cipolins are found, composed in great part of yellow calcite, and enclosing elliptical masses up to a foot (3 decimetres) across. These are made up of a mixture of different minerals, and are very variable in constitution. Two of them were found to have the following composition:—

1st.—The first is composed of large crystals. With the naked eye, calcite and a white felspar in large plates, green pyroxene, pyrites and quartz, can be distinguished. The examination of microscopic sections shows that the pyroxene belongs to the scarcely pleochroic sea-green variety described above.

All the constituents are granular. Besides those mentioned sphene is present in strongly pleochroic, bright pink crystals. The felspar is oligoclase. The calcite forms rounded grains, playing the same part as the other minerals: it also occurs in little patches due to secondary infiltration.

2nd.—Seen with the naked eye, the second is green, there being visible green hornblende, calcite, a white mineral not attacked by acids, and pyrite.

The microscope further discloses abundance of wernerite in large patches, sphene, oligoclase and zoisite.

The hornblende is of a pale green colour, with a rather strong pleochroism—

$\mathfrak{c}$, bright sea-green,
$\mathfrak{b}$, brownish-green,
$\mathfrak{a}$, bright-yellow,

with $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$.

Extinction on $\infty P\infty(010)$ occurs at about 22° from the direction of elongation. The crystals are greatly elongated in the direction of the edge of the zone $\infty P\infty.\infty P\infty.(100)(010)$, and often form long needles placed irregularly side by side, and separated by patches of calcite.

As in the preceding rock, the calcite exists in two different states, secondary

[1] *Op. cit.*, p. 310.

[2] *Sic*: doubtless Kurnegalle, about 50 miles N.-E. of Colombo. *Vide* footnote, p. 9—*F.R.M.*

calcite being here very abundant. These lenticular nodules of variable composition recall those that Becke has described in the pyroxenic gneiss of Seybererberg, near Weissenkirchen[1]

In the present case, they are of great theoretical interest, for being evidently derived from the cipolins in which they occur, they present a composition closely comparable to that of the pyroxenic gneisses of the same region, and, in a certain measure, allow us to assume, for the latter, a similar origin.

MICA-SCHISTS.

The upper part of the gneissose series is composed, in the neighbourhood of Salem, of hornblendic mica-schists, quartzose rocks containing iron-ore (magnetite), and a peculiar hornblende (grünerite), mica-schists with chromiferous mica (fuchsite) rocks, containing ripidolite and clinochlore, and finally chloritic schists and sericite-schists, which are very like the archæan schists.

We will rapidly pass in review those of them, and those only, which are of petrographical interest.

Hornblendic mica-schists.

These mica-schists are confusedly stratified rocks, formed of little needles of olive-green hornblende. The rock is easily broken, when these little crystals become separated.

In microscopic sections they are transparent, slightly coloured and pleochroic with:

$\mathfrak{c}$, greenish-white,
$\mathfrak{b}$, greenish-white,
$\mathfrak{a}$, colourless,

$\mathfrak{c} = \mathfrak{b} > \mathfrak{a}$.

The rock contains a considerable quantity of magnetite in rounded grains.

Mica-schist with grünerite.

These rocks have an extremely well-marked stratification. Sometimes they are rich in quartz; sometimes, on the other hand, they contain none, and are formed exclusively either of hornblende (*grünerite*), or of the same hornblende with magnetite. They were found 12 miles (*5 lieues*) west of Salem.

Usually the rock is strongly impregnated with oxide of iron, and has a reddish colour; when this tint is less marked, the rock is brownish yellow. When it is composed exclusively of hornblende, it occurs in the form of but slightly coherent, large fibrous masses; when including quartz and magnetite, it becomes, on the contrary, very tenacious.

By treatment for some minutes with boiling hydrochloric acid, all the products of infiltration may be dissolved, and the hornblende appears in yellowish olive-green transparent crystals of 2 or 3 centimetres, resembling the hypersthene of the rocks of the Capuchin (Mont-Dore), but having only an extremely feeble pleochroism, with a maximum absorption parallel to $\mathfrak{c}$.

[1] Tsch. min. petr. Mittheil., iv (1882), 374.

The microscope shows that this hornblende, which is much elongated in the direction of the edge $\infty\bar{P}\infty.\infty\breve{P}\infty.(100)(010)$, does not possess a definite form. The extremities of the crystals are irregular: the cleavages $\infty P.\infty P.\ (110)(1\bar{1}0)$ are very clearly marked, and also the [gliding planes] parallel to $oP.(001)$.

In sections normal to the vertical axis, the two prismatic cleavages may be observed to form an angle of about 124°.

Polysynthetic twinning on $\infty\bar{P}\infty.(100)$ is very common. Extinction on $\infty\breve{P}\infty.(010)$ occurs at 25° from the trace of the prismatic cleavages. The double refraction is very strong:

$$\gamma - \alpha = 0{\cdot}05.$$

All these characters are similar to those that I have noticed in the exclusively ferriferous variety of hornblende found in the mica-schists of Collobrières (Var) associated with ores of iron.

The reddish colour of this hornblende, when examined in large specimens, is due to a sort of envelope of hematite, which coats each crystal, and which can be removed by acids, as has been said above. The hornblende is fusible before the blow-pipe to a black magnetic glass: its chemical composition is the same as that of the grünerite of Var.

The rock is formed, besides, of magnetite without definite form, and of quartz in grains of about half a millimetre with very distinct outlines, which are often emphasized by ferruginous infiltrations. The foliation of the rock is largely dependent on the orientation of the hornblende.

Mica-schist with fuchsite.

This mica-schist was obtained by Leschenault from the Kaveri,[1] about 40 miles (17 *lieues*) west of Salem. It belongs to the same geological horizon as the rock just described, from which it only differs in the substitution of mica for hornblende and magnetite.

It is a strongly schistose rock, composed in great part of white translucent quartz, sometimes tinted green by inclusions of emerald-green mica, which is localized in layers, the foliation of the rock being thus produced. Certain varieties, in which the green mica is very abundant, are susceptible of a fine polish.

The laminæ are hexagonal, but always more or less jagged.

The pleochroism is well marked, even in microscopic sections:—

$$\left.\begin{matrix}\mathfrak{c}\\ \mathfrak{b}\end{matrix}\right\}\ \text{bright-green.}$$

$$\mathfrak{a},\ \text{colourless.}$$

The colour is of a fine emerald-green, in thick plates.

The plane of the optic axes is perpendicular to $\infty\breve{P}\infty.(010)$:

$$2\,E = \text{about } 55.$$

In respect to its properties this mica is very near the fuchsite of Zillerthal: before the blow-pipe it gives the re-actions of chromium.

The great mass of the rock is composed of a little oligoclase, and much quartz.

The two chloritic rocks mentioned above are formed, one of a fine green

[1] "*À Caveri.*" The river, where due west of Salem, is about 30 miles distant.—*F.R.M.*

clinochlore in plates 2 centimetres in diameter ($2\ E = 45°$ across the positive bisectrix); the other of a granular ripidolite (1 positive axis), which is strongly pleochroic in microscopic sections—

e, colourless.
o, green.

The double refraction is feeble:

$$\varepsilon - \omega = 0{\cdot}003.$$

This rock is remarkable from its analogy with those found in certain parts of the Alps, and notably at Zermatt. Like the Zermatt rock, it encloses crystals O.(111) of magnetite which attain nearly a centimetre in their longest direction.

CHAPTER VIII.—SUMMARY AND CONCLUSIONS.

The title of this memoir itself shows sufficiently that we have had no intention of writing a complete monograph on the pyroxenic gneisses and scapolite-bearing rocks. We have only desired to lay the foundation of a work that we propose to carry out.

The great abundance of scapolitic gneisses is shown in the first line of our memoir, and we are persuaded that this category of rocks that have been little studied up to the present time will be found in most regions where the upper series of the gneisses exists.

From the descriptions given in the preceding chapters it is possible to draw some general conclusions.

In the upper part of the series (*l'étage*) ζ^1 of the gneisses, pyroxenic rocks occur which are characterized by a special facies. They never constitute beds of a great thickness that can be followed for long distances. They form lenticular masses, elongated in a fusiform way, and often disposed one after another in lines (*entraînées*). They are conformable in stratification with the acid gneisses of the series under discussion, and follow all the contortions and deformations of the latter.

Sometimes, as in Finisterre, Waldviertel, &c., they are associated with hornblendic gneisses, often garnetiferous (eclogites), forming alternations of various rocks *ad infinitum*, and passing into each other by insensible gradations. Sometimes (Norway and Saxony) they are associated directly with granulitic gneisses, presenting numerous passages into these more acid rocks.

Viewed with reference to their mineralogical composition, these *pyroxenic gneisses* are characterized by the association of minerals, small in number, but varying considerably, both in composition and proportion, not only in different regions, but in the same locality.

They are rocks with a compact appearance, and colour varying from greenish gray (Brittany) to dull green (Saxony). They are very tenacious, and in general finely crystalline. The varieties passing into hornblendic gneisses are the darkest. Those passing into granulitic gneisses (Saxony, Odegarden), by the introduction of quartz and orthoclase, are of a bright colour; their constituents are easily distinguished with the naked eye, and the general facies of the rock recalls that of granulitic gneiss.

As a rule, these gneisses are not foliated; their crystallo-laminated (*cristallo-phyllienne*) nature is indicated by the distribution of the coloured minerals in parallel planes. Except in some special cases this disposition is more apparent under the microscope than to the naked eye.

The most simple composition is found in a granular mixture of *triclinic felspar,* or *scapolite,* with *pyroxene. Sphene* is rarely absent (Saxony), and is sometimes very abundant. *Pyrrhotine* is of common occurrence.

Next to the above, *hornblende,* in the varieties passing into hornblendic gneisses, *quartz, apatite, zircon, garnet, hypersthene. wollastonite* and *calcite* are the most frequent constituents. As for the felspars, *anorthite* (Roguédas, Ceylon), *labradorite* (Brittany, Saxony, &c.), *oligoclase,* (Brittany, Saxony, Waldviertel, Norway), *albite-* (New York) or *orthoclase* (Brittany), may be present, either singly or more than one together, even in different parts of the same bed.

The minerals of the *scapolite* group play the same part. Divers types of the family (*dipyre, wernerite,* &c.,) are met with in these rocks, as will be seen further on, but, conversely to what is true for the felspars, one species of scapolite is characteristic of any given locality (*dipyre* in Brittany, Spain and Pierrepont, *wernerite* at Odegarden, Waldviertel, Ceylon. &c).

The relative proportions of the white constituents, and of the ferro-magnesian minerals, are not less variable; sometimes, as in Ceylon, and occasionally in Brittany, the white minerals form nine-tenths of the rock, enclosing a few grains only of pyroxene; sometimes, on the other hand (United States), the pyroxene forms exceptional rocks by itself.

The *pyroxene* appertains to malacolite; it is of a bright green colour, rarely very pleochroic (Saxony). In two localities (Ceylon and Odegarden) the scapolite s accompanied by peculiar, intense-green pyroxenes.

Wollastonite occurs either as an original constituent (Ceylon, Herero, and the United States), or as a product of the decomposition of basic felspars. *Allanite,* crystallographically allied to epidote, is frequent in these rocks (Finisterre, Norway, Waldviertel). *Epidote* is a primary constituent of them. In the anorthite gneiss of Salem we have discovered a new species of mineral—*fouquéite.*

Turning to the hornblendic gneisses accompanying the above pyroxenic gneisses, they offer still more remarkable examples of variations in composition. We have examined them incidentally, and have been obliged in studying them to adopt a special classification for each locality, generally based on the nature of the dominant hornblende. The pegmatoidal associations of bisilicates, either in the mass of the rock, or in coronas around the garnets, may be observed in all the localities enumerated above.

We have seen that in Norway there is a scapolite-bearing-rock independent of the gneisses, and that it was produced by the metamorphism of gabbro under the influence of veins of apatite. The study of this ophitic gabbro has led us to the examination of a French exposure of the rock that we have discovered, and in which we have found petrographical peculiarities (coronas around olivine) similar to those of the Scandinavian gabbros. Finally, still another scapolite-bearing-rock has been described. It is an eruptive one, of which the history has not been completely elucidated.

From a genetic point of view, it is interesting to remark that in divers localities

(Loire-Inférieure, Waldviertel, Ceylon, United States), the pyroxenic gneisses are in evident relation with the calcareous metamorphic rocks. We have shown how the existence of scapolite in these rocks is generally in direct relation with these limestones.

We have likewise studied the junctions of these scapolite-bearing pyroxenic gneisses with granulite, in Brittany. By means of petrographical peculiarities that we have noticed there we have been able to explain the remarkable modifications that we have met with in the similar rocks of Norway and of America, although we are unacquainted with the eruptive granulite which has produced them in the latter localities.

EXPLANATION OF THE PLATE.

Fig. 1.—Corundum-and sillimanite-rock (Salem).

Fig. 2.—Anorthite-gneiss—

8, Anorthite; 20, *Pyroxene*; 35, *Fouquéite.*

Fig. 3.—Scapolitic gneiss (Salem)—

8, Anorthite; 14, *Sphene*; 16, *Scapolite (wernerite)*; 20, *Pyroxene*; 25, *Garnet.*

Fig. 4.—Wollastonite-bearing rock (Ceylon)—

8, Anorthite; 16, *Scapolite*; 20, *Pyroxene*; 25, *Garnet*; 47, *Wollastonite.*

Fig. 2

Fig. 3

Fig. 1

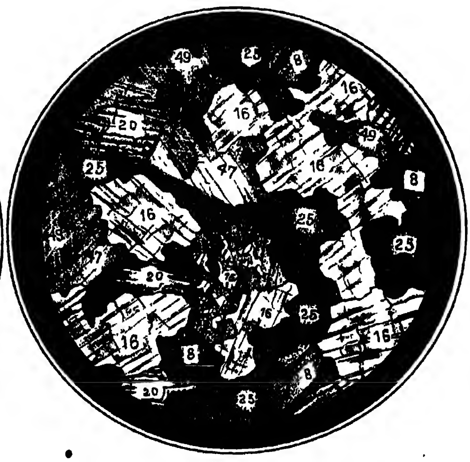

Fig. 4

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 8.—ENDING 31ST JULY 1891.

Director's Office, Calcutta, 31st July 1891.

The staff of the Survey remains disposed in the following parties:—

Madras Party.—R. B. FOOTE, F.G.S., Senior Superintendent, Cuddapah District.

Burma Party.—THEO. W. HUGHES HUGHES, A.R.S.M., Superintendent, Tenasserim.
FRITZ NOETLING, Ph.D., Palæontologist, Upper Burma.
H. WARTH Ph.D., Transferred to Madras.

Punjab Party.—C. L. GRIESBACH, C.I.E., Superintendent.
C. S. MIDDLEMISS, B.A., 2nd Grade Deputy Superintendent.

Baluchistan Party.—R. D. OLDHAM, A.R.S.M., 1st Grade Deputy Superintendent.
Sub-Assistant Hira Lal.
Sub-Assistant Kishen Singh.

Darjeeling and Sikkim.—P. N. BOSE, B. Sc., 2nd Grade Deputy Superintendent.

Bengal Coal-Fields.—T. D. LATOUCHE, B.A., 2nd Grade Deputy Superintendent.

Assam.—P. N. DATTA, B. Sc., Assistant Superintendent.

Head-Quarters, Calcutta.—The Director; T. H. HOLLAND, A.R.C.S., F.G.S., Assistant Superintendent, Museum and Laboratory.

Most of the officers are in recess.

Mr. Hughes, after having closed up the season's work in Tenasserim, left Mergui for Rangoon where he is still occupied, in association with the Financial Commissioner of Burma, with reports on the progress of the tin exploration.

Dr H. Warth has been transferred to Madras where he is officiating in charge of the Government Central Museum.

Dr. Noetling continues in Upper Burma.

Mr. LaTouche concluded his season at the boring exploration in the Daltonganj coal-field. His report appears in the present issue of the Records.

Mr. Oldham returned to head-quarters, at the close of his field work in Baluchistan which he has carried on continuously for eighteen months; and, as a result, he has put up the several very useful reports mentioned below in the list of papers, &c., sent in to office for publication or record.

Mr. LaTouche availed himself of furlough for six months on the 24th of May 1891.

Mr. Griesbach returned from privilege leave on the 6th of July 1891, when he was ordered up to Simla for work there.

Mr. Middlemiss returned from deputation with the Black Mountain Expedition early in May, and is now in recess at Abbottabad.

The Director was on official duty with the Revenue and Agricultural Department at Simla from the 1st June to the 12th July, when he returned to head-quarters.

List of Reports and Papers sent in to Office for publication or record during May, June, and July 1891.

Author.	Subject.	Disposal.
R. LYDEKKER . . .	On a collection of fossil bones from Mongolia.	To appear in the Records, Geological Survey of India, for November next.
R. D. OLDHAM . . .	1. The Sub-recent and Recent Deposits of the valley plains of Quetta, Pishin, and the Dasht-i-Bedaolat.	Record.
	2. On the mode of occurrence and probable distribution of artesian water in the valley plains of the Quetta and Pishin District.	To Baluchistan Agency.
	3. Report on the outflow of Petroleum in the Robdar Valley, Bolan Pass.	To Government of India.
	4. Report on the Petroleum resources of the country adjoining the routes to Quetta.	Ditto.
	5. Memorandum on the possibility of finding Petroleum near Sukkur on the Indus.	Ditto.
	6. Report on the Coal Resources of Quetta and the routes leading to it.	Ditto.
	7. Report on the Geology of Thal Chotiali and part of the Mari country.	To appear in Records, Geological Survey of India, for November.
	8. Notes of a tour from Quetta by Kachh to Ziarat, Hindubagh, and back.	Record.
	9. Memorandum on the mode of occurrence of petroleum.	Ditto.
T. D. LATOUCHE . .	Boring exploration in the Daltonganj coal-field.	Appears in the current Records, Geological Survey of India.
DR. H. WARTH . . .	Note on a remarkable cave piercing the Tham Pra ridge, in the Mergui District, Lower Burma.	To appear in the Records, Geological Survey of India, for November.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of May, June, and July 1891.

Substance.	For whom.	Result.
Chalcopyrite and pyrite, from Pachiphani, Sikkim, for copper.	P. N. Bose, Geological Survey of India.	Contains 14·06 per cent. of copper (Cu).
6 specimens of coke, from Raniganj, for assay	Kilburn & Co., Calcutta.	
A specimen of coal, from Raniganj, for assay	Ditto ditto.	
A specimen from Abu Cantonments for determination.	Major W. Loch, Assistant Resident, Western Rajputana States.	Consists of iron pyrites in decomposed diorite containing smaller grains of pyrites and magnetite with plagioclase-felspar, quartz, epidote, chlorite, hornblende and acicular crystals of apatite. Calcite infests cracks in the rock and a highly refracting mineral occurs in granules (perhaps sphene).
Mineral for determination . . .	Rai Ishwari Prasad, Patna.	
A specimen of decomposed gneiss for sulphur.	Barry & Co., Calcutta.	
4 specimens of coal, from the Pench River, Chindwara, for assay.	The Chief Commissioner, Public Works Department, Central Provinces.	(see below)

	Pit No. 2, near Colonel Ashburner's well.	Pit No. 3-B in stream.
Moisture	5·94	5·14
Volatile matter . . .	30·22	30·54
Fixed carbon . . .	52·60	46·22
Ash	11·24	18·10
	100·00	100·00

Does not cake.
Ash—pale white.

	Pit No. 6, Runnoby's 1st layer.	Pit No. 6, Runnoby's 2nd layer.
Moisture	4·74	4·90
Volatile matter . . .	26·56	27·00
Fixed carbon . . .	36·44	36·50
Ash	32·26	31·60
	100·00	100·00

Does not cake.
Ash—pale white.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of May, June, and July 1891—contd.

Substance.	For whom.	Result.
2 specimens of coal, from Upper Burma, for assay.	GISBORNE & Co., Calcutta.	
Mineral from boring (depth 154') near Police Thana, Quetta Cantonments, for determination.	R. D. OLDHAM, Geological Survey of India.	Chalybite and pyrites with carbonaceous matter.
2 specimens of minerals from range of hills running E. and W. 2 miles S. of Mowkalianpur, near Behar.	CHAS. PURDY.	
2 specimens of minerals for determination .	C. MACDOUGAL CLARK.	
1 ditto ditto . . .	G. B. REYNOLDS, Warora.	
2 ditto ditto . . .	E. C. WHITEHEAD.	
1 ditto ditto . . .	WOMESH CHUNDER BOSE, Calcutta.	
A specimen of quartz, for gold . . .	BARRY & Co., Calcutta.	
Amethystine and smoky quartz, with mica and pyrite, for gold.	R. B. FOOTE, Geological Survey of India.	Contains no gold.
A specimen of coal from the Nengbrang, Assam, for assay.	P. N. DATTA, Geological Survey of India.	Cakes, but not very strongly. Moisture . . . . 5·24 Volatile matter . . . . 37·48 Fixed carbon . . . . 32·94 Ash . . . . 24·34 TOTAL . 100·00 Ash—pale white.
2 specimens of quartz, from Sonapet, for gold.	HEILGERS & Co., Calcutta.	
Quartz, with decomposed mica-schist and earth, from Upper Burma, for gold.	The Financial Commissioner, Burma.	Contains no gold.
Several specimens of minerals and rocks from the Bhagulpore district, for determination.	F. BRAIDWOOD, Calcutta.	

Notification by the Government of India during the months of May, June, and July 1891, published in the "Gazette of India," Part I.—Leave.

Department.	No. of order and date.	Name of Officer.	Nature of leave.	With effect from	Date of return.	Remarks.
Revenue and Agricultural Department.	$\frac{904}{8\text{-}12}$ S., dated 7th May 1891.	T. H. D. LaTouche	Furlough .	24th May 1891.	...	
Do. .	$\frac{1111}{8\text{-}17}$ S., dated 28th May 1891.	R. D. Oldham .	Privilege leave	30th July 1891.	...	

Annual Increments to Graded Officers sanctioned by the Government of India during May, June, and July 1891.

Name of Officer.	From	To	With effect from	No. and date of sanction.	Remarks.
	R	R			
R. D. Oldham . .	800	850	1st May 1891.	Revenue and Agricultural Department No. $\frac{1330}{8\text{-}21}$ S., dated 11th June 1891.	

Postal and Telegraphic Addresses of Officers.

Name of Officer.	Postal address.	Nearest Telegraph Office.
R. Bruce Foote . . .	Yercaud	Yercaud (Madras).
T. W. H. Hughes . . .	Calcutta	Calcutta.
C. L. Griesbach . . .	Simla	Simla.
R. D. Oldham	Calcutta	Calcutta.
P. N. Bose	Darjiling	Darjiling.
T. H. D. LaTouche . . .	Calcutta	Calcutta.
C. S. Middlemiss . . .	Abbottabad . . .	Abbottabad.
P. N. Datta	Calcutta	Calcutta.
F. Noetling	Pakokku	Pakokku.
Hira Lal	Calcutta	Calcutta.
Kishen Singh	Calcutta	Calcutta.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1891. [November.

On a Collection of Mammalian Bones *from* Mongolia, *by* R. LYDEKKER B.A., F.G.S., *&c.*

The evidence of the existence of a Pliocene mammalian fauna in Western China, closely allied to the Siwalik fauna of India, has been gradually accumulating since 1870, when Sir R. Owen communicated a memoir to the Geological Society's Journal [1] on this subject. Most of the specimens described in that memoir were obtained from caverns in the province of Szechuen, although one came from marly beds on the eastern coast near Shanghai. All were referred by their describer to new species, but the present writer subsequently came to the conclusion that the two elephant teeth in the collection belonged to Siwalik species. Still later the cast of an elephant's tooth, the original of which was obtained from strata on the Upper Whang-ho in Kansu, was submitted to myself, and identified with the Siwalik *Elephas insignis* [2]. Other Siwalik species were subsequently identified from China by the aid of specimens in the British Museum during the compilation of the "Catalogue of Fossil Mammalia," most of which appear to have been derived from deposits other than those of caverns. The most important addition to our knowledge of Chinese fossil mammals was, however, made by Prof. Ernst Koken [3], based upon specimens collected by Baron von Richthofen in the caves and 'loess' of Yunnan, and a few from Shansi.

We have, therefore, evidence that the Chinese Pliocene mammalian fauna ranged from Yunnan in the south-west northwards through Szechuen to Kansu, and thence

[1] Quart. Journ. Geol. Soc., vol. xxvi, p. 417 (1870).
[2] Palæontologia Indica, ser. 10, vol. ii, p. 289 (1884).
[3] Palæontologische Abhandlungen, vol. iii, pt. 2 (1885).

eastwards through Shensi to Shansi; its extreme eastern limit being indicated by the elephant's tooth from Shanghai.

Hitherto we have had no evidence of the extension of this fauna to the northward of Kansu, although the circumstance that the Whang-ho flows into Mongolia south of the Ala-Shan mountains (through which there is a gap into the great Gobi desert), suggests that it must have reached these regions. Recently my friend Prof. Howes put into my hands a small collection of mammalian bones and teeth which had been sent to Prof. Huxley as coming from Mongolia.

Although some of the specimens are not unlike Siwalik fossils, others are quite different; and since the latter closely resemble the Szechuen cave-bones, I have no doubt that they are all of Chinese origin, and have no reason to suspect their reputed source. The list of specimens is as follows, *viz.*:—

1. Part of the mandible of a hyæna.
2. The second phalangeal of a large ruminant.
3. Part of the innominate bone of the same.
4. The lower end of the humerus of a small ruminant.
5. The lower end of the metacarpus of the same.
6. Fragment of the lower end of a radius probably belonging to the same.
7. Two fragments of horn-cores, one of which may have belonged to the same species.
8. An upper premolar of a horse.
9. A last upper molar of the same.
10. The upper end of the metatarsus of the same.
11. The upper end of a first phalangeal of the same.
12. The lower end of a similar bone.
13. An entire first phalangeal of the same.
14. Part of the axis vertebra of the same.

With the exception of No. 14, all the specimens are thoroughly mineralized, the cancellæ and medullary cavities of the bones being filled either with crystalline spar, or with a hard reddish clay, or sandstone. From their pure white colour, it seems probable that Nos. 4, 5, 6, and 8 were obtained from a cavern-deposit; the matrix adhering to them being a reddish sandstone. No. 1 is of a pale-brown colour, but also has a somewhat similar matrix; the teeth being stained of a greenish colour, quite unlike the pure white of No. 8. Since the condition of this jaw is not unlike that of many Punjab Siwalik fossils, I think it was probably obtained from an ordinary sedimentary deposit. A similar origin may, perhaps, be assigned to some of the other specimens, such as Nos. 2, 9, 10, 11, and 12, which have a more clayey matrix; Nos. 10 and 11 being not unlike some of the fossils obtained from the typical eastern Siwaliks. With regard to the origin of the remaining specimens I am more doubtful.

The interest attaching to the specimens consists not only in that they carry (if their reputed place of origin be the true one) the Chinese Pliocene mammalian fauna to a more northern district than has been hitherto known, but that they indicate two Indian Siwalik species not previously recorded from Chinese territory. Moreover, one of them affords important information as to the structure of a Siwalik species.

Hyæna macrostoma, Lyd. The first specimen I have to notice is the fragment of a hyæna's jaw (No. 1) represented in woodcut, fig. 1.

This consists of the imperfect hinder portion of the left ramus of the mandible, containing the broken carnassial tooth (M. 1), and the roots of the fourth premolar. That it belongs to a hyæna is evident from the structure of the carnassial, which, while of the feline type, differs from that of all *Felidæ* in possessing a well-developed hind talon. This tooth has a length of 0·0235 and a width of 0·01. The roots of the last premolar indicate that that tooth was of a very long and narrow form, quite different from that of existing hyænas. Moreover, the present specimen is characterized by the circumstance that the last premolar and the carnassial are placed in the same antero-posterior line, whereas in the more typical hyænas the long axis of the one is very oblique to that of the other.

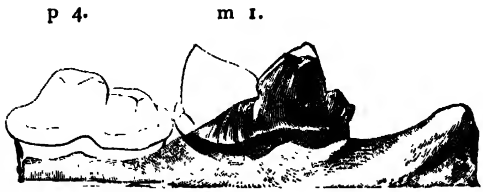

Fig. 1. Outer view of the superior border of part of the left ramus of the mandible of *Hyæna macrostoma* from Mongolia, $\frac{1}{1}$.

In all these respects this specimen agrees with two very aberrant species of hyæna, respectively known as *Hyæna chæretis*, Gaudry,[1] from the Pikermi beds of Attica, and *H. macrostoma*, Lydekker,[2] from the Punjab Siwaliks; the former being the type of Hensel's genus *Lycyæna*. Compared, indeed, with the lower jaw of *H. macrostoma* (of which there is a cast in the British Museum) the present specimen can only be distinguished by the somewhat smaller depth of the ramus—a feature which may well be due to difference of age or sex. And it may be noted that while the present specimen (as deduced from the amount of wear the tooth has undergone) belongs to a comparatively young animal, the Siwalik jaw indicates a considerably older individual.

So far, then, as can be determined from the lower jaw, there are no reasons for separating the Mongolian hyæna from the Siwalik *H. macrostoma*. The interest of the present specimen does not, however, end here. Both in *H. chæretis* and *H. macrostoma* it has hitherto been unknown whether (as in *H. græca* and *H. sivalensis*) there was a second lower molar, or whether (as in all the existing species) this tooth was absent. The present specimen shows its absence. Further, in the Pikermi species the lower carnassial has a very large hind talon, and an inner cusp rising from the hinder lobe of the blade. The carnassial being broken off in the Siwalik jaw, it was impossible to determine its relation to the Pikermi species in these respects. In the present specimen, however, there is no cusp on the inner side of the carnassial, while the talon is smaller than in *H. chæretis*. If, therefore, the Mongolian jaw be rightly referred to *H. macrostoma*, it enhances the distinctness of that species from *H. chæretis*, while in any case its specific distinctness from the latter is clearly marked.

Apart from the question whether it is advisable to distinguish generically these two species under the name of *Lycyæna* (in regard to which I have considerable doubt), it is clear that *H. macrostoma* (if the present specimen really belong to it) presents the same relation to *H. chæretis* in regard to the structure of the lower carnassial as is presented by the striped hyæna (*H. striata*) to the spotted hyæna

[1] Animaux Fossiles et Géologie de l'Attique, pl. xv, figs. 1—5.

[2] Palæontologia Indica, ser. 10, vol. ii, pl. xxxvii, pl. xxxviii, fig. 4, pl. xxxix, fig. 6.

(*H. crocuta*); so that we have the same line of specialization going on independently in different groups.

Gazella, sp.—The existence of a species of gazelle is indicated by the distal extremity of a right metacarpus (No. 5) represented in woodcut, fig. 2.

This specimen is readily distinguished from the metacarpus of the sheep and goats by the rounded contour of the lower part of the front of the shaft, as well as by the absence of the deep depressions immediately above the trochleæ on this aspect, and also by the position and direction of the nutrient foramen. It is equally well distinguished from the metacarpus of the Saiga, and likewise from this bone in the deer, in which there is a very deep anterior groove. Compared with the metacarpus of *Gazella subgutturosa*, there is such a close resemblance as to indicate that the fossil bone likewise belongs to a gazelle. It is rather smaller than the corresponding bone of *G. subgutturosa*, and would thus agree better with that of the somewhat larger *G. gutturosa*, with which I have been unable to compare it. Since, however, all the other Chinese fossil mammals appear to belong to extinct species, it is probable that the same will hold good for the gazelle, although I do not intend to propose a new name for it. It is probable that the distal extremity of the left humerus (No. 4), as well as the imperfect distal portion of the right radius (No. 6), belonged to the same individual as the one which owned the matacarpus. Of two fragments of horn-cores (No. 7) the longer is compressed from side to side after the manner of modern gazelles, and probably belongs to the species under consideration.

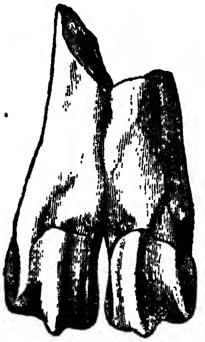

Fig. 2. Anterior aspect of the distal extremity of the right metacarpus of *Gazella*, sp.; from Mongolia, ½.

No remains of gazelles are described by Dr. Koken among the specimens obtained from Yunnan; neither are there any species of that group living at the present day in China proper. The Mongolian deserts are, however, the exclusive home of *Gazella gutturosa*, and it is, therefore, especially interesting to find a predecessor of that species in our collection. So far, indeed, as they go, these specimens serve to confirm the correctness of the locality assigned to the collection, and indicate the prevalence of desert conditions in Mongolia since the Pliocene. Indeed, the whole series of specimens belongs to groups of animals, *viz.*, hyænas, gazelles, oxen,[1] and horses, of which at least some living representatives are confined to more or less completely desert regions.

Bos, sp. Among the Yunnan collection Dr. Koken has figured teeth referable to the genus *Bos*, in its wider sense, and it is therefore highly probable that the specimens Nos. 3, 4, should belong to the same genus.

Equus sivalensis, Falc. and Caut. In my description of the remains of this species from the Siwaliks[2] I came to the conclusion that its affinities were closest with the Kiang (*Equus hemionus*) of Tibet and Mongolia, although the upper cheek-teeth are distinguished by the smaller antero-posterior length of the

[1] The Yak inhabits the desert-like Tibetan plateau.

[2] Palæontologia Indica, ser. 10, vol. ii, p. 92.

anterior pillar of the premolars, and the larger size of the first tooth of that series. In India the species is unknown westward of the Jhelum. As regards its dental characters *E. sivalensis* occupies a position intermediate between *E. stenonis*, of the European Pliocene, and the modern representatives of the genus.

In the memoir cited (pages 77-78, pl. vi, figs. 14, 15), Dr. Koken described and figured a right[1] fourth upper premolar and third molar of an *Equus* from Yunnan. The premolar is stated to be very like the corresponding tooth of *E. sivalensis*, but distinguished by the smaller development of the posterior valley and the thinner coating of cement. The molar is distinguished by the greater depth of the same valley, and the greater plication of the enamel. The resemblance of both teeth to those of the Kiang is mentioned.

Of the equine remains from Mongolia, I shall only notice the two teeth, of which the crowns are figured in woodcut, fig. 3. Both the teeth (which are more or less damaged) belong to the right side, and are in a medium condition of wear. The one represented as *a* (which is the more worn) is the fourth premolar, while the other (*b*) is the third molar. The latter is imperfect posteriorly, and indicates a smaller animal than the one to which the former belonged.

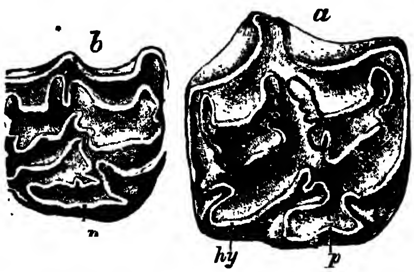

Fig. 3. Crown surfaces of fourth right upper premolar (*a*), and third molar (*b*) of *Equus sivalensis*; from Mongolia. ½. *p*. anterior pillar; *hy* posterior do.

There can be no hesitation in regarding these teeth as specifically identical with those figured by Dr. Koken. The premolar has, however, a deeper posterior valley (the notch immediately to the left of *hy*), and thus shows that the size of this valley is of no specific importance, varying to some extent with the degree of wear. In the molar the plication of the enamel of the central islands is less than in the Yunnan example; but I attach very little importance to such variations. The cement of the premolar is thick.

Compared with the corresponding teeth of the upper jaw of *E. sivalensis*, figured in the "Palæontologia Indica," ser. 10, vol. ii, pl. xiv, fig. 1, an almost exact identity will be found; and I have accordingly no hesitation in referring both the Mongolian and Yunnan teeth to that species.

Bearing in mind the relationship which I have seen reason to believe exists between *E. sivalensis* and the living *E. hemionus*, it is of considerable interest to be thus able to trace the range of the former into the very area occupied by the latter. Since, moreover, we have no evidence of the occurrence of *E. sivalensis* in the Western Punjab, it may be suggested that *E. onager* of Baluchistan, Kach, and Persia may possibly have had a different origin, and is not, therefore, specifically the same as *E. hemionus*, although the two are practically indistinguishable.

[1] Described in the text as left, but figured (unless reversed) as right.

Further note *on the* Darjiling Coal Exploration, *by* P. N. Bose, B.Sc., F.G.S., *Deputy Superintendent, Geological Survey of India.*

The possibility of coal seams, similar to those of the Lisu-Ramthi area, being found in the Damuda ground west of the Tistá; the proximity of this ground to several existing lines of cart and one line of railway-communication with the plains; and the fact that a considerable balance was left from the grant made during the previous season by the Government of Bengal, were considerations which led to the continuance of the coal exploration.

The entire Damuda area between Pankhabári and the Tistá was examined in some detail, and special attention was paid to the ground just by the Tistá Valley cart-road.

The *modus operandi* of the exploration being similar to that of the previous season need not be detailed again; and as the pits sunk disclosed no promising seams, the details with regard to them will probably serve no useful purpose. A few sections, however, bearing upon the geology of the area, are given in the following notes, which must be taken as supplemental to the systematic treatment of the subject by Mr. Mallet in Memoirs, Volume XI, Part I. The economic result, though disappointing, is not without importance, as the question of the finding of workable seams in the area explored, which crop up from time to time, may now be safely said to be set at rest.

(*a*)—*The Tistá Valley Cart-road Section.*

At and a little above Sivok (which is situated at the debouchure of the Tistá into the plains), the Tertiary sandstones are soft, fine grained, highly micaceous, and have a rather low south-western dip. Pockets of lignite were found in them just by the cart-road. On the east side of the Tista also the river section exposes similar sandstones with south-eastern dip, overlaid by very coarse recent deposits. The lowness and the southern direction of the dip are noteworthy, and will be referred to when we come to discuss the important question of the elevation of the Himalayas.

The inclination becomes northern about a mile north of Sivok. It still continues rather low for some distance; and soft, massive, fine-grained, micaceous sandstones still form the chief rock.

Just south of the Andera Jhora, and close to its junction with the Tistá, massive conglomeratic sandstones are encountered. They are also seen on the opposite bank of the Tista with a rather high north-western dip. These conglomerates apparently form the top of the Tertiary system, as they do in the area further eastward. They are succeeded *to all appearance without a break* by shales and sandstons, which, however, have a Damuda facies about them.

Further north, thin seams of coal are seen by the Tistá close to the cart-road. A rather low, south-eastern dip is observable in them, though somewhat indistinctly. On the south side of the Ruyem or Kali Jhora a great thickness of crumbly earthy rocks with carbonaceous shales and thin seams of coal, the whole resting upon sandstones and having a distinct southern dip, is met with. These rocks are continued in a south-western direction along the strike to the head of the Kali Jhora, where an immense slip affords a grand view of them. The slip has affected a large area, and the narrow neck of land which separates the Kali Jhora and the Sivok Jhora is gradually giving way.

Just under the bridge over the Kali Jhora the rock is a much fissured gray sandstone, dipping very high, almost vertically, in a north-western direction. There is evidence here of great disturbance.

Proceeding from the bridge northward for about five furlongs, there is found a great development of sandstones with thin seams of coal and occasional bands of carbonaceous shales, striking N.E.—S.W. The seams are scarcely over a foot and a half in thickness, but some of the coal is of fair quality and cakes.

The following section just north of the junction of the Kali Jhora with the Tistá gives an idea of the mode of occurrence of the coal:—

2'.—Brownish sandstones with very thin seams of *coal.*

2'.—Good *coal.*

12'.—Sandstones with strings of *coal.*

1'.—Good *coal.*

4'.—Rather soft brownish sandstones with very thin seams of good coal.

The strata are rather contorted. Usual dip N.N.W. about 70°.

Further northward, along the river, rock is not so uninterruptedly visible. Here and there quartzitic sandstones, and at one place rather soft sandstones, are met with.

Close to the junction of the Sitikhola with the Tistá, the Dalings come in, their dip as well as that of the Damudas being northern.

North of the rest-bungalow on the Kali Jhora, and west of the cart-road, there is a flat some 200 feet above the road, and about 300 above the river bed. The greater portion of its thickness above the road is formed of recent deposits—alternations of sand and shingle; the latter at places compacted into hard rock.

The following section of the Damudas in the Kali Jhora, commencing from the bridge in ascending order, partly natural and partly exposed by digging, may be given here.

MASSIVE QUARTZITIC SANDSTONES.

17'.—Rather soft sandstones with thin seams of *coal;* dip very high.

43'.—Rather soft sandstones with thin seams of *coal;* dip very high, with occasional bands of carbonaceous shale. Dip N. N. E., 60°. The sandstones are fine grained and partly ferruginous. They are intersected by joint planes, the faces of which are very smooth and are encrusted with thin films of carbonaceous matter. The strike of these planes here is E.N.E.—W.S.W., and the inclination is nearly vertical and southern.

28'.—Rather massive sandstones with abundance of carbonaceous matter and very thin seams of *coal.*

3'.—Finely laminated sandstone. The strike here becomes E.N.E—W.S.W.

6".—Good *coal.*

6".—Carbonaceous shale.

1'.—Good *coal.* The thickness of these thin seams of coal is very variable.

29'.—Massive sandstones.

7″.—Good *coal.*

5′.—Sandstones with thin bands of carbonaceous shales crumpled up together.

1′.—Good *coal.*

2′ 9″.—Sandy carbonaceous shales and very thin *coal.*

60′.—Massive, gray, much fractured sandstones, with a little occasional carbonaceous matter. The strike here is very nearly E.—W.

5′.—Thin sandstones and coal crumpled up together.

7′.—Rather soft, whitish sandstones. Bedding planes strike nearly E—W. These are cut obliquely by joint planes striking N. E.—S. W. Carbonaceous matter occurs in thin foliæ along these planes.

2′.—Thinly laminated carbonaceous shale and *coal* crumpled up together. Here the strike changes to E.S.E.—W.N.W.

5′.—Thin sandstones and carbonaceous shales crumpled up together.

1′.—Good *coal.*

42′.—Rather massive, soft sandstone.

4′.—Carbonaceous shales and *coal* crumpled up together.

11′.—Sandstones.

2′.—Carbonaceous shale and *coal.*

2′.—*Coal.*

2′.—Sandstones.

2′.—Carbonaceous shale and thin *coal.*

15′.—Sandstones.

3′.—Carbonaceous shales with thin *coal.*

3′.—Sandstones.

3′ 6′.—Carbonaceous shales and *coal.*

8′ 6″.—Sandstones.

3′.—Carbonaceous shales.

3′.—*Coal* with thin lenticular bands of quartzite.

6′.—*Coal* with bands of thinly laminated quartzitic sandstone. At one place one coal seam was found to be a little over 2 feet in thickness, but traced along the strike the thickness was found to be reduced to a few inches. Dip W. N. W.

23′.—Sandstones. The dip here changes to N. N. W.

1′ 6″.—Good *coal,* with very thin lenticular bands of quartzite.

9′.—Sandstones with abundant carbonaceous matter.

1′ 9″.—Good *coal.*

SANDSTONES.

[The section is more or less covered up for two furlongs.]

13′.—Sandstones, false-bedded, buff, fine-grained, fespathic, with nests of carbonaceous matter.

3 .—Rather soft sandstones with thin *coal,* the two crumpled up together.

5′.—Rather soft gray sandstones.

5′.—Carbonaceous shales, thin seams of *coal,* and thin lenticular bands of quartzitic sandstones.

1'.—Fine-grained ochreous sandstone.

20'.—Fine carbonaceous shales with thin seams of *coal* and occasional bands of ferruginous sandstone, the whole crumpled up together.

21'—Sandstones with occasional nests and strings of carbonaceous matter.

5'.—Thinly laminated carbonaceous shales with thin seams of *coal*, not more than 2 or 3 inches in thickness.

3' 6".—Highly felspathic sandstones.

9".—Carbonaceous shale.

13'.—Felspathic sandstones. [The dip so far is N.N.W. about 60°.]

2' 6"—Carbonaceous shales and sandstones. The dip here becomes W. N. W.

1' 6".—Rather good *coal*.

7'.—Whitish felspathic sandstones.

1' 9".—Carbonaceous shale with very thin *coal*.

14'.—Sandstones.

5'.—Rather soft, thinly laminated, brownish sandstones with abundant carbonaceous matter.

2 .—Carbonaceous shale with thin *coal*.

8'.—Sandstones.

1'2".—*Coal*.

15'.—Sandstones with thin seams of *coal*.

21'.—Thinly laminated sandstones and carbonaceous shales with thin *coal*.

5'.—Carbonaceous shales with thin *coal*.

5'.—Grayish sandstones with *coal*, of which one seam is about 9 inches in thickness. The dip here changes to N.W.

24'.—Massive gray sandstones with abundance of carbonaceous matter.

30'.—Partly covered up, partly thinly bedded sandstones and carbonaceous shales.

9".—Rather good *coal*.

7'.—Alternations of hard, dark shale and thin sandstones.

6".—Coaly shale.

10".—*Coal*.

1'.—Carbonaceous shale.

1'.—*Coal*.

3".—Shale.

1'.—*Coal*.

172'.—Sandstones, carbonaceous shales, and thin seams of much altered *coal*, the whole much crushed and crumpled up. The sandstones prevail. They are mostly quartzitic; and those in contact with the coal have their contact surfaces smoothed and polished, and indented into hollows and furrows in a peculiar manner.

450'.—Mostly covered up. Some coaly shale, sandstones, &c., are exposed in a streamlet about half way.

3'.—*Coal*.

48'.—Alternations of rather soft, fine grained sandstones, carbonaceous shales and thin *coal*. The dip is very high all the way. Strike N.N.E.—S. S. W.

Further up the Kali Jhora there are met with, first quartzites and quartzitic sandstones, and then a succession of crumbly, intensely fractured, greenish gray gritty mudstones, quartzites and carbonaceous shales with thin seams of coal which continue to the head of the Jhora.

(*b*)—*West of the Tista Valley.*

Proceeding westward the band of the Damudas is found to be considerably attenuated along the Látpanjor spur. They widen out again by the Mana Jhora, a tributary of the Mahánadi. There are several seams of coal in the reserved forest east of Mana Jhora, but they are much disturbed and greatly altered by igneous intrusions. Several outcrops of coal are visible in the Mahánadi; one just below the godown of the Simring Tea Estate, measured 11 feet. The dip is rather high, about 65°, and usually points N. N. W.

The high scraggy ridges, formed of massive Tertiary sandstones and conglomerates sloping with the dip slope which form such a characteristic feature in the landscape between the Chel and the Mahánadi, lose their definition south-east of Tindáriá, and are almost entirely lost by the railway at Sepoydhurá (Rungtong). Hence westward, as far as Phankhabári, the Tertiaries are not distinguishable from a distance. This loss of definition is due to attenuation, as well as to the absence of the massive conglomeratic bands.

Along the railway line the Tertiary boundary which, as usual, cannot be drawn without difficulty, is just a few yards below the railway station at Rungtong. Hence proceeding northward (nearly across strike), alternations of shales, sandstones, and thin seams of coal are met with. The thickest of the coal seams is not more than 3 feet in thickness. The shales, which are rather soft and slightly ferruginous, predominate about Chunbatti, and just at the loop here a thin seam of indifferent coal is exposed. Beyond this there is an immense thickness of slaty shales and flags on which the Government Engineer's bungalow stands. We then come upon alternations of sandstones, carbonaceous shales and coal which extend up to the Railway Station at Tindaria. The Dalings come in just a little beyond. As the section about Tindaria have been given in detail by Mr. Mallet, and as my diggings did not disclose any seam of importance, it is needless to give details of the latter.

The several branches of the Chirangkholá expose a number of coal seams, but none of more than 6 feet in thickness, and none that would cake.

The Rattundong tea garden (included in the Selim tea estate) west of the Rohini river, stands on a gently sloping bay-shaped flat, about 6 furlongs wide. It is strewn over with huge masses of gneiss, which must have come all the way from Kurseong; and its thickness is made up of recent detrital deposits, in which large partially rounded blocks of gneiss and quartzite prevail. Rock is seen *in situ* only in the bed of the Rohini, and there, too, it is less often seen than not.

The Rakti exposes a much better section, which has been described by Mr. Mallet. The Bámanpokhri flat just west of the Rakti is similar to the Rattundong flat just mentioned. In some ravines at the head of this flat several rather promising outcrops of coal were encountered, but digging through them they were found to be of small thickness.

(c)—*Quality of Coal.*

The following table contains the analyses of a few samples made in the Survey laboratory:—

	Rungtong Jhora, by D.-H. Railway, lower outcrop.	Above junction of Kali Jhora with the Tista, by the Cart-road.	Kali Jhora, Tista Valley.	Kali Jhora, Tista Valley.
Moisture	5·74	3·00	2·52	4·92
Volatile matter	16·80	12·16	11·76	13·90
Fixed carbon	41·82	72·60	39·72	54·98
Ash	35·64	12·24	46·00	26·20
	100·00	100·00	100 00	100·00
	Cakes, but not strongly. Ash, light gray.	Does not cake, buts sinters slightly. Ash, light red.	Cakes, but not strongly. Ash, light red.	Cakes, but not strongly. Ash, light gray.

Notes *on the* Geology *and* Mineral Resources of Sikkim, *by* P. N. BOSE, B.Sc., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With one map; [*will appear in next part of the Records*].)

I.—PHYSICAL GEOGRAPHY.

To the east Sikkim is bounded by a ridge which forms the watershed between it on one side and Bhután and the Chumbi portion of Thibet on the other, the streams on the Sikkim side being tributaries of the Tistá and those on the Bhután and Chumbi side feeders respectively of the Jaldhaká and the Torsá. The ridge, which is sometimes called the Cholá range from one of the passes in it, rises in elevation northward, the principal peaks proceeding in that direction being Lingtu (12,617 feet), Gipmochi (14,523 feet), Chukurchi (15,283 feet), Dopendikáng (17,325 feet), Black rock (17,570 feet), and Powhunri (23,190 feet). The chief passes on the eastern frontier are Pembiringo, Jalep (14,390 feet), Cholá (14,550 feet), and Thankalá (16,000 feet).

The northern boundary is drawn on the Survey map (Sheet No. 7 $\frac{\text{N.-W.}}{1}$) along a lofty snow-capped ridge of which Kanchanjháu (22,550 feet) and Chomiumo (22,290 feet) are the best known peaks. The natural line of watershed lies a little further north along a less elevated ridge passing through Bhomtso north of the Cholamo lake; and the boundary in a more recent map[1] is drawn along this line. The streams to the south of it are feeders of the Tistá, and those to the north are tributaries of the Arun. The best known passes on the northern frontier are Donkiá (18,100 feet), Kongrálamu (16,000 ?), and Naku (17,000 feet).

[1] Published in the Survey of India Report on the explorations in Sikkim, Bhutan, and Thibet (1889).

The western boundary is formed by a well-defined ridge known as the Singalela ridge from the principal pass in it. It is continued southward into the Darjiling district, and is traceable as far as Gum, south of Darjiling.

The principal peaks in this ridge, for which there are names, are Singalela (12,130 feet), Lampheram (Sagu, 12,130 feet), Negadachenphuk (14,770 feet), and Kanchanjinga (28,150 feet). It forms the watershed between Sikkim and Nepal, the streams on the Sikkim side being feeders of the Tistá and those on the Nepal side tributaries of the Ganges. The chief passes on the western frontier are Kanglanangma (16,740 feet), and Chia Bhanjan (10,320 feet).

The southern boundary of Protected Sikkim is formed by the Rummam, the Rangit, the Tista, the Rungpo and the Rhenock spur.

Sikkim is essentially a mountainous country without a flat piece of land of any extent anywhere. The mountains rise in elevation northward. The high serrated snow-capped spurs and peaks, culminating in the Kanchanjinga, which form such a characteristic and attractive feature in the scenery of Sikkim, are found in this direction. The northern portion of the country is deeply cut into steep escarpments, and, except in the glacial valleys (the Lachen and the Lachung), up to a height of about 8,800 feet, is not populated. Southern Sikkim is lower, more open and fairly well cultivated.

This configuration of the country is partly due to the direction of the main drainage, which is southern. The Himálayas on the Indian side must have sloped to the south from the earliest geological times, when the gneiss which constitutes their main body was elevated. For, all the later rocks—the submetamorphic slate group, the coal-bearing Damudas, and the Tertiaries—which fringe the outer Himálaya are evidently formed of detritus carried by rivers like the Tistá from the north.

The physical configuration of Sikkim is also partly due to geological structure. The northern, eastern and western portions of the country are constituted of hard massive gneissose rocks, capable of resisting denudation to a considerable extent. The central and southern portion, on the other hand, is chiefly formed of comparatively soft, thin, slaty and half-schistose rocks, which are denuded with facility; and it is this area which is the least elevated and the most populated in Sikkim.

The trend of the mountain system, viewed as a whole and from a distance, is in a general east-west direction, nearly parallel to the predominant rock-strike. The chief ridges in Sikkim, however, with the exception of the Donkiá ridge, run in a more or less north-south direction, that is, at right angles to the strike of the rocks. The Singalelá and the Cholá ridges have been mentioned above. Another north-south ridge runs through the central portion of Sikkim separating the Rangit from the Tistá valley. Tendong (8,676 feet) and Moinám (10,637 feet) are two of its best known peaks. This north-south direction of the principal ridges is due no doubt to the original southern slope of the Himálaya. The Rangit and the Tistá, which form the main channels of drainage, run nearly north-south, that is, transversely to the rock-strike. The meridional ridges throw off lateral spurs, which run roughly parallel to the strike; and corresponding to these spurs there are streams running in the same direction.

The valleys cut by the rivers and their chief feeders are very deep. The valleys of the Rangit, the Tistá and of their chief tributaries are generally not less than

5,000 feet in depth. They are rather open towards the top, but usually attain a steep gorge-like character as we approach the beds of the rivers. As a consequence of this and also of the comparative insalubrity of the lower portion of the valleys, all the monasteries and principal villages are situated at an elevation ranging from 4,000 to 6,000 feet.

The snow-capped ridges in the northern portion of the country send down glaciers which at present usually come down to about 13,500 feet; those from the Kanchinjinga appear to descend about 1,000 feet lower. The perpetual snow-line in Sikkim may be approximately put down at 16,000 feet, so that the glaciers descend 3,500 to 2,500 feet below that line. Formerly they used to descend much lower than at present. Láchung, for instance, of which the elevation is 8,790 feet, stands at the foot of an immense terminal moraine. The Bidangcho lake, on the road between Gnáthong and Jalep pass, at an elevation of 12,700 feet, is dammed at the southern end by a bank of boulders which are distinctly of glacial origin. Moraines occur also about Thangme in the Prágchu valley at an elevation of about 13,000 feet. The retreat of the glaciers backward towards the *névé* in these cases has been recent, and the ancient moraines evidencing their advance are still *in situ*. But the excessive rainfall of Sikkim amounting annually to probably no less than 200 inches makes the removal and rearrangement of the glacial boulders a question of very short time; and once brought within the action of the torrential streams the boulders soon lose all traces of their glacial origin. The peculiar configuration of the hills passed over by glaciers is also soon lost owing to pluvial denudation. The glacial valleys, as, for instance, the Prágchu, the Láchen, and the Láchung valleys, are open and ◡ shaped, and this shape is one of the most reliable evidences of their origin. But after the retreat of the glaciers, the streams taking their place soon cut the valleys down deeply into V-shaped gorges, and the striking distinction between glacier and river valleys is soon effaced. Thus, owing to excessive rainfall, traces of past glacial action are liable to extinction in Sikkim, and it is impossible to tell how far the glaciers extended in remote times. The lowest height of glacial extension for which I found unmistakeable evidence is that of Lachung (8,790 feet). Below Lachung also, down to a height of about 7,000 feet, the valley is open and has a glacial look about it.

Valleys to which glaciers come down or whence these have but recently retired abound in small lakes or tarns, which are dammed in at the outlet by moraines. Some of these tarns have been described by me in my "Journal of a trip to the glaciers of Kabru, Pandim, &c." (Records, Vol. XXIV, pt. 1, p. 46). The Bidangcho lake, 3 miles north-east of Gnáthong, is the best instance I came across of a glacial lake in a valley whence the glacier has recently retired. It is 1⅓ mile in length, and its greatest breadth is ½ mile.

The following hot springs are known in Sikkim :—

1. *Phut Sachu.*—On the east side of the Rangit river, 2 miles north-east of Rinchinpong monastery. Situated amongst dark-coloured, massive, siliceous limestones; hot fetid water bubbles up at several spots. Temperature at one spring 100·4° F. The springs are situated in the bed of the river, which at the time I visited them (March) was dry. These springs are referred to in Dr. Oldham's "Thermal springs of India" (Mem., Vol. XIX, pt. 2, p. 32) as Phug Sachu.

2. *Ralong Sachu.*—On the west bank of the Rangit river, about 2 miles N.N.W. of Rálong monastery. Elevation about 3,100 feet. Situated amongst finely laminated phyllites with abundance of veinquartz, at a height of about 100 feet above the bed of the river. Hot-water flows out through fissures at several places. The temperature of the hottest spring close to where it comes out is 131° F.; in a reservoir constructed for bathing purposes it is 118·4° F. The temperature of another spring close to where the water flows out is 114·8°; in the reservoir it is 107·6°. (The temperature of an adjacent stream was found to be 53·6°). A whitish deposit which effervesces strongly on the application of hydrochloric acid is formed at the mouths of the springs. It is stained green at places with carbonate of copper, due, no doubt, to the springs passing through cupriferous strata. It is very likely these springs that are referred to in Dr. Oldham's list as "Puklaz-Sachu," "about one day's journey from the monastery of Pemlong" (*op. cit.*, p. 32). Probably "Pemlong" is meant for Ralong. I heard of a hot spring about half a mile north of Rálong Sachu, which I had not time to visit.
3. *Yeumtong.*—On the east bank of the Láchung river, half a mile below Yeumtong river. Though I passed the springs I could not get at them owing to the bridge over the Láchung not having been constructed at the time of my visit (May). They are described in Dr. Oldham's list (*op. cit.*, p. 32). "The discharge amounts to a few gallons per minute. The temperature at the source is 112½°, and in the bath 106°. The water has a slightly saline taste. It is colourless, but emits bubbles of sulphuretted hydrogen gas, blackening silver." (Hooker, Him. Journ., 1855, Vol. II, p. 126.)
4. *Momay.*—"Hot springs burst from the ground near some granite rocks about 16,000 feet above the sea, and only a mile below the glacier [of Kinchinjhow], and the water collects in pools; its temperature is 110°, and in places 116°." (Hooker, "Himalayan Journal," 1855, Vol. II, p. 140; see also Dr. Oldham, *op. cit.*, p. 33.)

II.—GEOLOGY.

The following publications contain scattered notes on the rocks of the country:—

1854.—"Himalayan Journals," by Sir Joseph Hooker.

1854.—Journal, Asiatic Society, Bengal, Vol. XXII, pp. 540, 611:—"Notes upon a tour in the Sikkim Himalayas along a portion of the western, or Nepal frontier," by Captain W. S. Sherwill.

1862.—Journal, Asiatic Society, Bengal, Vol. XXXI, p. 457. "Journal of a trip undertaken to explore the glaciers of the Kanchanjinga group," by Major J. L. Sherwill.

1871.—Journal, Asiatic Society, Bengal, for 1871, p. 367:—"Account of a visit to the eastern and northern frontiers of Sikkim," by W. T. Blanford.

1891.—Records, Geological Survey of India, Vol. XXIV, pt. I, p. 46:—"Extracts from the Journal of a trip to the glaciers of the Kabru, Pandim, &c., undertaken in September 1889," by P. N. Bose.

1.—The Gneissic Group.

The rocks belonging to this group are the oldest, and constitute the main body of the Himálayas. From near Kurseong, south of Darjiling, to the northern frontier of Sikkim, it is uninterruptedly traced over a distance of some 75 miles in a straight line; whereas all the later rocks—the submetamorphic slate group, the Damudas, and the Tertiaries—together cover an area in the outer Himálayas nowhere more than 6 miles in width.

Two forms of the gneiss are met with—

(*a*) In Southern Sikkim, approximately south of the parallel of Jongri and Boktolá (about Lat. 27° 25′) the gneiss is highly micaceous and frequently passes into mica schists. Both muscovite and biotite occur, the former predominating. Hornblende, garnet, and schorl are the chief accessory minerals. Bands of quartzite are common. Veins of calcite occur at places, as near Lingtu by the road to Gnáthong. The gneiss is well foliated, and exhibits strongly marked features of disturbance, in that it is much folded and crumpled, especially in the extreme south about Darjiling. The prevailing strike is W.N.W.—E.S.E.

(*b*) In Northern Sikkim, as north and south-west of Jongri, about Lachung, &c., the gneiss is not quite so micaceous. Muscovite is either rare, or is entirely absent, but biotite is abundant. Schorl and hornblende are the chief accessory minerals. Intrusive granitic rocks occur as dykes and sheets; in some of them muscovite is well developed. The northern gneiss is apparently not so highly disturbed as the southern; the dips being, as a rule, rather easy, indeed, sometimes as low as 10°. The prevailing strike is the same as that of the southern gneiss, the general direction of dip being north-eastern.

The northern gneiss agrees in some of its petrological characters with the "Central Gneiss" of Stoliczka. As the southern gneiss, however, was uninterruptedly traced into it, and as no physical break was perceptible anywhere, they are very likely of the same age. Mr. Medlicott takes the same view in the Manual of Indian Geology.[1]

The relation between the Gneissic group and the next group (the Dalings), which includes submetamorphic slates, phyllites, &c., is far from clear. At the eastern boundary between the two groups, which passes by Gántok, the present capital of Sikkim, the Dalings apparently underlie the gneiss, the dip of both being north-eastern. So do they also at the western boundary, which passes by Pemionchi, the first monastery in Sikkim, the dip there being north-western. At the southern boundary, which is in the Darjiling district, and which appears to be faulted, the dips of both the groups are southern. Wherever the junction between the two groups is observed, the Dalings appear to underlie the gneiss; and the fact that the former pass into mica schists at places near the junction makes it appear as if there was a passage from the one to the other group. Indeed, Mr. Mallett considered the gneiss as more recent than the Dalings.[2] But the former being presumably the older rock, it would be preferable to find some other explanation for the apparent underlie of the Dalings; and an explanation will be suggested later on.

[1] Vol. ii, 597, 614.
[2] Mem. vol. xi, pt. I, p. 42.

The fact that near the junction everywhere the gneiss dips in the same direction as the Dalings shows that the former was largely affected by the disturbing forces which tilted up the latter. The low north-eastern dip in the northern gneiss is due to disturbance at some previous period; possibly it accompanied the elevation of the gneiss.

2.—*The Dalings.*

This name was given by Mr. Mallet to a group of submetamorphic rocks, after a place called Daling in the Darjiling district. Phyllites form the predominant rock in this group. At the boundary between it and the gneissose rocks they pass into silvery mica schists; in fact, in this position the passage is sometimes so gradual that it is difficult to say where the one group begins and the other ends. Dark clay slates with thick quartzite bands prevail near Chákang, Páchikháni (south of Pakyang), &c.; the workable copper ores invariably occur amongst these rocks. Gritstone is sometimes met with just south of Namchi: conglomerate is not known. Impure siliceous limestone is found north-east and north-west of Namchi; and highly carbonaceous shales occur in the Mangpurjhora just south of Namchi, by the Rangit, east of Chákang, and by the Rummám near Gok (south of Chákang).

Igneous rocks are rare. A rather thick band of gneissose granite was met with between Murtám and Rámthek, which continues for some distance northward, as well as southward, forming the serrated peaks D. 5 and Maphila. It is probably of intrusive origin, and of great interest in connection with the age of the intrusive rocks in the gneissie group in northern Sikkim. An unquestionably intrusive dioritic-looking rock was encountered penetrating through slates by the road between Song and Tikobu. All these rocks will be described in detail hereafter.

In Sikkim, Dalings occur somewhat in the form of a dome-shaped anticlinal. On the south side the dip is southern; east of the Rangit it is chiefly E.N.E. to N.E.; west of that river the inclination is north-western; and on the north side, as near Ralong, the dip is mainly northern. The southern boundary between the Dalings and the gneissose rocks, which passes a little north of Darjiling, was shown by Mr. Mallet to be faulted. The eastern boundary passes by Gántok, and the western by Pemionchi. As in the case of the Damuda-Tertiary and the Daling-Damuda boundaries in the Sub-Himalayas, both of these boundaries may represent "lines of original contact, possibly modified by subsequent faulting."[1] The Daling rocks would in this case have to be supposed as deposited in a lake, of which steep gneiss-escarpments formed the sides: the lower gorge of the Tista below its junction with the Rangit which, except close to its debouchure, is composed of Daling rocks, forming the outlet of such a lake. The Dalings, it should be noted in this connection, unquestionably bear the impress of lacustrine, rather shallow-water deposits, falsebedding being noticeable at places. In fact, they recall to one's mind the micaceous clays and sandstones of Tertiary age in the outermost fringe of the Sub-Himalayas. By subsequent tangential pressure, which caused their disturbance, the Dalings would be tilted up against the original gneiss-escarpments in such a manner as to present an appearance of conformable underlie and of faulting. The greater metamorphism of the Dalings at the boundary between them and the gneissose rocks—a fact which has been noted before—may be account-

[1] Mem., vol. iii, pt. 2, p. 102, vol. xi, pt. 1, p. 48; Rec., vol. xxiii, pt. 4, p. 244.

ed for by the greater pressure to which they would be subjected there owing to the resistance offered by the older gneissose rocks.

The Dalings have suffered considerable disturbance. The slates and phyllites frequently exhibit crumpling and contortion; and the dips are, as a rule, rather high, being seldom below 45°.

The following sequence of strata in ascending order is met with near Chákang:—

(*a*) Massive, coarse, quartzites, or quartzite-sandstones, with a lenticular band of carbonaceous shales.
(*b*) Dark slaty shales, which are cupriferous at places.
(*c*) Phyllites passing into micaceous schists at places.

If the gneissic rocks be correlated to the infra-silurian gneiss of the North-West Himalayas, the Dalings must represent the slate series of this area,[1] and Mr. Griesbach's Haimantas of the Central Himalayas.[2] Lithologically, the resemblance is great, except that no conglomerate has been found in the Dalings; and the limestone, so well developed in the Simla area, is but poorly represented in Sikkim.

III.—ECONOMIC GEOLOGY—COPPER.

§ *1. General remarks.*

Copper ores are very widespread in Sikkim, and constitute the main source of its prospective mineral wealth.

The following generalisations arrived at by Mr. Mallet with regard to the copper ores of the Darjiling district *generally* hold true for Sikkim also:—

(1) "All the known copper-bearing localities are in the Daling beds. Some are, it is true, situated in the transition rocks between the Dalings and the gneiss, but none in the genuine gneiss itself.
(2) "The ore in all is copper-pyrites, often accompanied by mundic. Sulphate carbonate and oxide of copper are frequent as results of alteration of the pyrites, but they occur merely in traces.
(3) "The ore occurs disseminated through the slates and schists themselves, and not in true lodes."[3]

With regard to the first generalisation, it may be noted that copper ores have been found at several places noted below, in the gneiss itself, though usually within a short distance of its junction with the Dalings. The gneiss ores, however, do not appear to be so rich as those in the Dalings, and have never been worked. With regard to the third generalisation, the ore, in one case at least, that of Páchikháni, appears to occur in lodes.

Within the Dalings the richest ores (those of Páchikháni and Ráthokháni, for instance) occur amongst greenish gray, rather soft, slaty shales. The gangue in this case consists of the shale, much hardened by infiltrated quartz, or of quartz alone.

The methods of mining, dressing of the ore and of smelting are much the same

[1] Manual, vol. ii, pp. 595 *et seq.*
[2] Memoirs, vol. xxii, p. 49.
[3] Memoirs, vol. xi, pt. 1, p. 72.

as those described by Mr. Mallet for the Darjiling district[1]. Deep mining is not practised, owing chiefly to the want of suitable apparatus for draining the mines. At Pachikhani the only place where copper ores are worked on a tolerable scale in Sikkim, the deepest mine goes down only to about 55 feet; and I found water had collected to such an extent even at this depth that the miners were talking of abandoning it, though the ore is very rich. Many mines, as, for instance, those of Tukkháni (south-east of Námchi), have been abandoned owing to the difficulty of draining the water with the primitive appliances used by the miners. As the ore almost invariably gets richer with depth[2], deeper working at the abandoned mines with improved appliances may be reasonably expected to yield good results. Mining under the present conditions may be said to be abandoned just when it begins to be most profitable.

The miners are all Napalese and belong to the caste of Mangars. The men and boys work in the mines, and the women dress the ore. Smelting of the dressed ore is performed by the caste of Kamis. This is considered a very low caste, and a Kámi would not be allowed to enter the house of a Mangar or any other Hindu of a higher social status. The houses of the Mangars run north-south, whereas those of the Kámis have their length directed east-west; so that in a mining village, like that of Páchikháni, it is easy to distinguish the house of a miner (belonging to the caste of Mangar) from that of a smelter (Kámi). Scarcely any mining work is done during the rains, and even in the working season, which extends from October to June, an occasional heavy shower of rain puts a stop to it for days. On the occasion of my last visit to the mines (11th April) I found only a few women dressing the ore, and there was no one working at the mines owing to the heavy rainfall of the previous day. The number of men, women, and children who find employment one way or another—mining, dressing of the ore, smelting, &c.,—probably does not exceed 300 any day.

The miners work in gangs on their own account, and not for hire, each gang under a headman. For every five seers of copper turned out, one goes to the Kámi, or the man who conducts the smelting, and four remain as the share of the miners. The whole of the copper turned out must be sold to the party who has the lease of the mines called *taksari* at a price fixed by him. The average annual outturn at Pachikhani is estimated at about 6,000 *dharnis*, or 450 maunds of copper, valued at Rs. 12,000, at the rate of Rs. 2 per *dharni*, which is the price paid by the lessee to the miners. If we take the average number of the men, women, and children maintained by the mines at 200, Rs. 60 falls to the share of each individual, which, considering that but little mining work is done during the rains, is very fair wage. Indeed, the mining people here are probably better off than in most other parts of India. They are well housed, well clad, and well fed; and the women make a fair show of trinkets.

The *taksari* (or lessee) sells the copper at Rs. 2-8 per *dharni*. Thus he makes a profit of about Rs. 3,000, out of which he has to pay Government dues, which, I

[1] *Op. cit.*, p. 69.

[2] This was unquestionably found to be the case at Pachikhani, the only place where I could compare surface with comparatively deep-seated ores. A specimen of picked ore from the surface yielded on assay 14·06 per cent. of copper, whereas an average sample from a depth of about 50 feet from surface gave 20·31 per cent.

am told, amount to Rs. 250, and maintain his establishment, consisting of a clerk known as *Bhansari*, and a few chaukidars. The present lessee of Pachikhani is Luchmi Das Newar, who owns extensive landed property in Sikkim.

§ 2. *Ore-localities.*

Copper-ores occur at the following localities:—

1. PÁCHIKHÁNI.—The only place besides Ráthokháni where copper ores are worked at present. The old mines which are now deserted were situated close to the junction of the Rorochu and the Rahrichu just by the Gántok road. The mines worked at present occur a mile further north, about 3 miles south of Pakyang, also close to the Gántok road. The roofs of the drifts in the old Páchikháni have fallen in, as is the case with all deserted mines. At the entrance of one of the galleries I found stalactitic and stalagmitic deposits stained green by carbonate of copper, also traces of copper pyrites in slaty rocks. The dip is north-eastern; but on the east side of the Rorochu it is E.S.E. The stream probably marks the position of a fault.

The new Páchikháni stands on slaty shales, which have a greenish hue when wet, but appear gray when dry. These are superposed by schistose quartzite, in which very thin slightly greenish foliæ of shaly matter occur. The strike varies between N.W.-S.E. and W.N.W.-E.S.E., and the dip is north-eastern, about 35°.

There are five principal galleries communicating with each other, and which follow the courses of the ores. The drift being worked at the time of my visit was about 4 feet in height and 3 feet in width, or from 40 to 50 feet below the surface; the roof being supported by timbering on a large scale. Chips of bamboos are used as lights. The gangue consists of quartz and much hardened shale; soft slaty shale, as has been mentioned before, being the country rock. The ore is extracted from the veinstone by chisel and hammer. The richest ore occurs at the deeper and suddenly sloping end of this drift, below 40 feet, but the men were then in water, and were talking of ceasing to go any further down. If the water were let out—and this could be done without serious difficulty by proper contrivance—I have no doubt the ore would be found to go down much deeper. Here we have to all appearance a lode.

The ore is, as usual, copper pyrites mixed with a little mundic. The analysis of a sample taken at random from this deeper part gave 20·31 per cent. of copper. I was informed at the mines that one maund of ore yielded 20 seers of *cheku* (regulus), and that 4 seers of *cheku* gave 1 seer of copper; so that from a maund of ore there is obtained about 5 seers, or 12 per cent., of copper. The copper is sent from the mines in flat pieces. It is again refined by those who work it up into vessels. Five seers of mine copper yield four on being refined.

2. RHENOCK.—About half-way between Páchikháni and Rhenock, on the south side of the Rungpo (or the Rarhichu, as it is called on map), and close to the bridge over it, there is exposed a fine section of the Dalings in which indications of copper are found. The cupriferous rocks in descending order are—

Slaty shales, with bands of segregated quartz, in which traces of copper pyrites are found.

3"-Quartz, with copper pyrites . .	Dip E. N. E. about 45°.
1'-Slaty shales	
6"-Quartz, with copper pyrites . .	

Here the ore apparently occurs in segregated veins parallel to the bedding.

3. LINGUI.—About 2 miles o the east of the last-named locality and a mile south of Lingui monastery at the junction of the Rungpo and the Ronglichu, copper pyrites occurs in highly quartzose gneiss dipping N.E. about 45°. The cupriferous band was found to extend about 100 yards, and is about 6 feet in thickness.

4. RANGLICHU.—About 3 miles[1] east-north-east of the Ranglichu rest bungalow, at the junction of a stream coming down from Pángolá, with the Ranglichu, I picked up a few pieces of schistose quartzite in which copper pyrites and bornite (?) are disseminated along foliation planes. I did not find the ores *in situ.* I have no doubt they occur some distance up the stream towards Pángolá. In this case the ores occur in the heart of the gneissic group.

5. LINDOK.—About half-way, on the new road between Gántok and Tumlong, close to the village of Lindok, there occur, interstratified with gneiss, talcose schists with pyrite, chalcopyrite, bornite, copperas and blue-vitriol, with traces of epsomite. The thickness of the cupriferous band in a stream just by the road was found to be about 2 feet, and it was traced for about 38 feet; dip 40° E.N.E. A little to the south-east of the stream, also by the road, there is similar schist with copper ores in the gneiss, but the thickness here is not more than 7 inches.

6. BHOTÁNG.—Situated about 6 miles east-south-east of Páchikháni, close to the junction of the Tistá and the Rungpo, along a precipitous scarp of slaty rocks overlooking the Tistá. The mines here were worked for about 20 years and abandoned only last year. Luchmidas, proprietor of Pachikhani, was the lessee. The average annual outturn was about 3,000 *dharnis,* or 225 maunds of copper.

The ore, as usual, is chalcopyrite, occurring in a hard jaspery-looking rock; but it is much mixed up with iron pyrites, more so than at Pachikhani. There are two ore bands, parted by 10 or 12 feet of slaty shales, which, too, are more or less impregnated by ore. Of these two bands the upper averages about 3 feet in thickness, and the lower 2 feet 6 inches. They run parallel to bedding and appear to be what are called segregated veins. The dip is about 45° E. to E.S.E. Levels are driven along the courses of the ore bands. One I entered has gone for about 54 feet and then stopped owing to water filling in. If the water were let off, there is no reason why the ore should not be found workable deeper down.

The ore bands can be traced with the eye for some 200 feet along the strike on the north side. South of the levels they run for about 25 feet, and are then faulted against greyish and greenish soft slaty shales dipping north-eastward. On the south side of the fault the ore bands are met with at a height of about 100 feet above those on the north side.

An average sample from the old workings yielded on assay 12·21 per cent. of copper.

7. BARMIAK.—Near Barmiak, just south of the new bridge over the Tistá, at a place called Lingyathang, I found, on the east bank of the Tistá, traces of copper ore in some detached blocks of quartzite.

[1] It may be observed that distances throughout this paper are measured as the crow flies.

There is also copper ore near the head of a stream south of Barmiak, called Kalokjhora.

8. NAMPHAK.—There were found the merest traces of copper pyrites in a detached block at this village, close to the Tumlong road, between it and the Tista.

9. DAJONG.—Close to the head of the Rungpochu, about 3 miles N.W. of Yangong monastery, steep scarps of the Dalings are seen from a distance to be stained green by carbonate of copper at places. The place is almost inaccessible, and I could not explore it well within the time at my disposal. At one spot, about a mile and-a-half east of Dajong, there were met with chalcopyrite, along with peach and iron pyrites, in some profusion in quartzitic rocks. The percentage of copper, however, appears to be too low to pay working.

10. TEMI.—About 3 miles west-north-west of this village, close to the source of a stream called Rimpichu, there was found chalcopyrite in some abundance in very hard quartzitic rocks.

Trial pits were opened both here and at Dajong last year by a Nepalese named Parsa Sing, but have been abandoned.

11. TUKKHANI.—These mines are situated along a feeder of the Mangpurjhora, a tributary of the Rangit, three miles due south of Namchi. They were deserted some time ago owing to the excavations filling in with water. The ore is said to have been of excellent quality, better even than that of Páchikháni, though now but little is seen of it, the galleries having fallen in. Deep mining here would, I have no doubt, give good results. The annual outturn of Tukkháni used to be about the same as that of Páchikháni, about 450 mnunds. The lessee was Luchmidas. The country rock is slaty shales, similar to those of Páchikháni.

12 MIK.—Two miles north-east of Tukkháni, close to the village of Mik, just by the Namchi road, copper pyrites were found disseminated in some very hard quartzites.

13. MONGBRU.—A mile north-east of this village, and about three miles south-south-west of Rálong monastery, close to the junction of a stream flowing from Rábonglá with the Rangit, there occur copper pyrites in clay slates, with segregated quartz.

14. RINCHINPONG.—Copper ores occur near this place, close to the source of a feeder of the Kulhait. The rock, as usual, is clay slate. The ores were worked on a small scale last year, but have been given up, as they did not pay.

15. BAM.—Two miles and a half south-south-west of Rinchinpong monastery, close to the village of Bam, there occur, by the Risi, copper ores in slaty shales with segregated quartz. The ore-bearing band was found only 6 inches in thickness at one place. The ore is found in traces on both sides of the river. The dip here is north-western about 65°.

16. RÁTHOKHÁNI.—Close to the village of Chákang, one days journey from Darjiling. The mines here are the oldest in Sikkim and were in working at the time of Mr. Mallet's survey of the Darjiling district.[1] The ore (copper pyrites) occurs in slaty shales, as well as in lenticular bands of segregated quartz, especially in the latter. Mr. Mallet found 9·1 per cent. of copper in a carefully selected average sample; it is not, therefore, nearly so rich as that of Pachikhani. The ore is confined to the east side of a ravine, which apparently marks the position of a

[1] *Op. cit.*, p. 75

fault: east of it the strata are inclined S.E. to N.N.E., whereas west of it the strata exhibit the normal dip of these parts, *viz.* N.W. The workings extend for about 100 yards on the east side of the ravine, pretty nearly along the strike of the strata. The main drifts run parallel to the bedding; but meandering passages across it in all directions also exist. The ore here appears to occur in segregated veins parallel to bedding, and there did not appear to be any indication of a true lode. Still, the oriferous beds may, I think, be advantageously followed deeper down. The difficulty of drainage has led to their abandonment; and at present the miners burrow here and there on a small scale.

Masses of quartz rock containing copper pyrites are found in the bed of the Rátho, a short distance below the mine. An average sample yielded on analysis 6·38 per cent. of copper.

§ *3. Summary and Concluding Observations.*

The following is a summary of the copper localities mentioned above:—

(*A*) *In the Dalings.*

Mines now worked . . .	Páchikháni. Ráthokháni (on a very small scale).
Mines recently abandoned . .	Old Páchikháni. Bhotáng.
Mines abandoned and wholly choked up.	Tukkháni.
Localities where trial openings have been made and abandoned.	Dajong. Rinchinpong. Temi.
Localities not yet tried	Rhenock. Bam. Mongbru. Barmiak. Namphak. Mik.

(*B*) *In the Gneissic rocks.*

Localities not yet tried . . .	Lindok. Lingui. Ronglichu.

The Nepalese miners have a very keen eye for copper ores; and the localities where they have been mining or rather burrowing—Tuk, Bhotáng, Rátho and Páchi—are certainly the most promising in all Sikkim. They work, however, in a primitive fashion; and the depth of the drifts which they run for the ore is limited by the water level of the nearest streamlet. As soon as a drift fills in with water which cannot be easily let out, it is abandoned. The deepest mine scarcely ever goes down below 60 feet from the surface; that at Páchikháni has scarcely reached this depth, and the miners intend abandoning it already, owing to the difficulty of draining it, though the ore is found to get richer with depth. It was chiefly this difficulty of drainage that led to the abandonment of Tukkháni, Bhotángkháni, and partly also of Ráthokháni. I have no doubt, Páchikháni also will be deserted as soon as the surface ores have been worked out. Deep mining on modern methods at these places, especially at Páchikháni, is likely to yield a very fair return.

Of the four places just mentioned Páchikháni appeared to me the most promising. This may partly be due to the fact that owing to the works here being in progress I could see for myself the exact mode of occurrence of the ore. However as the existence of at least one rich deposit here is known, this place ought to be tried first, in case Sikkim should attract mining enterprise, which it is likely to do in the near future. A sample taken at random from the deposit just mentioned yielded 20·31 per cent. of copper; and, from what the miners told me, the average yield from the entire mine is about 12 per cent. (5 seers of copper from one maund of ore). On the other hand, the picked ore from Ráthokháni was found by Mr. Mallet to contain not more than 8 or 9 per cent. of copper. At Bhotáng the ore contains rather too much of mundic. From what the miners who had worked at Tukkháni told me, the ore there at the point where it was given up appears to have been richer even than that of Páchikháni. I would not place much reliance upon such a statement uncorroborated by samples. Still, from all accounts, Tukkháni would be a very favourable place for trial, after Páchikháni.

Of the other localities the surface indications at Rhenock appear to be rather favourable.

IRON.

Occurs chiefly as pyrites in association with chalcopyrite. It is most plentiful at Bhotang, where magnetite also occurs. The iron ores have nowhere been put to any economic use.

LIME.

There is a vein of calcite in the gneiss at Lingtam about 3 miles north-east of the Ronglichu rest-bungalow. Lime was experimentally made from it, but it did not turn out quite satisfactory, being rather dark-coloured. There are beds of limestone in the Dalings, north-east and north-west of Námchi, but it is, as a rule, too impure to yield good lime. Lime in Sikkim is invariably made from tufaceous deposits, which abound in the vicinity of these beds, especially at Vok, near Námchi, whence large quantities of lime used at one time to go to Darjiling.

GARNET.

Is abundant in the gneiss and mica schists at places. But it does not appear to be good enough for the market.

NOTE ON A CUPRIFEROUS LATERITIC ROCK IN SIKKIM.

Mr. Lake in his excellent discussion on Laterite ("Memoirs," Vol. xxiv, pt. 3) observed that the general absence of laterite in the Himalayas "may be partly due to the want of continuous heat, and partly to the nature of the rocks, which are probably not so ferruginous as the traps and gneisses of the Peninsula."[1] There may be want of continuous heat at high elevations; but the climate of the deep valleys is essentially one of damp heat. There are also rocks in the Himalaya which are not less ferruginous than those which, in the Peninsula, have been decomposed *in situ* into lateritic rocks. If damp heat, aided by decomposing vegetation, be the chief cause of this lateritisation, as I believe it very likely is, laterite

[1] *Op. cit.*, p. 46.

ought to be found specially developed in the damp hot Himalayan valleys, clothed with exuberant vegetation. I think the reasons why the case is otherwise are,—1st, excessive rainfall; and secondly, steepness of the valley slopes. Before the rocks get sufficiently decomposed to be lateritised, they are clean washed away. The conditions, besides damp heat, which are favourable to the formation of laterite, *viz.*, moderate rainfall, and the existence of plateau or gently undulating land—are absent in the Sikkim Himalaya.

I found a tendency towards lateritisation on a small scale at places; and I may here notice a perfect lateritic rock which has been formed in a somewhat sheltered spot at Páchikháni, south of Pakyang. There are here heaps of débris from the copper mines by the side of a watercourse which have been lateritised at the surface. As the mines at this spot have only been worked for the last 2 or 3 years, the laterite must have been formed within that time. At Ráthokháni I found lateritisation had commenced at the surface of a heap of dressed ore not many weeks old ready for the furnace.

The Páchikháni laterite contains abundant concretions, from $\frac{1}{12}$th of an inch or less to $\frac{1}{4}$th of an inch in diameter, of which the lining is of green carbonate of copper, and the interior is filled by a mottled brown ferruginous substance. The fine débris which have been lateritised contain copper and iron sulphides; and the laterite is evidently the result of complicated chemical re-actions by which the iron has been separated, and the cupreous sulphide has been converted into the green carbonate.

Chemical *and* Physical notes *on* Rocks *from the* Salt Range, Punjáb, *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Geological Survey of India.* (With two plates.)

INTRODUCTION.

Before Mr. Wynne in 1878[1] published an account of his detailed survey of the geological structure of the Punjáb Salt Range, the district had, from its remarkable physical characters and from the value of its economic products, received a considerable amount of attention at the hands of both official and private observers. Since that year numerous facts in the geological structure of this district have been recorded; but a special interest in the question has lately been aroused by the interesting account Mr. C. S. Middlemiss has given of his re-examination of the area, and the hypothesis he puts forward to account for the remarkable position and origin of the salt-marl.[2]

At the request of several workers who are interested in this question of both scientific and economic importance, I have undertaken to devote a portion of my leisure to the study of the specimens which have been collected in the Salt-Range area by officers of the Geological Survey of India. In the notes appearing in this part

[1] Wynne. *Mem., Geol. Surv., Ind*, vol. xiv.

[2] "Notes on the Geology of the Salt Range of the Punjáb with a re-considered theory of the Origin and Age of the Salt-Marl." *Records, Geol. Surv., Ind.* vol. xxiv (1891), pp 19—42.

of the Records I give what I hope to be only a first instalment of the investigations into this subject which I propose to pursue. I hope to follow the examination of the bi-pyramidal quartz-crystals and preliminary investigation of its gypseous matrix with some notes on the chemical and physical characters of the dolomite, salt and associated minerals, as well as the Khewra trap.

Besides the light these specimens throw on the problems of local interest, the results so far obtained seem to offer some pertinent evidence on one or two questions of general mineralogical interest.

I.—On the Bi-Pyramidal Quartz-Crystals.

Mode of occurrence.

The mode of occurrence of these crystals, which have been used by the natives of the district for ornamental purposes under the name of "Márí diamonds," has received the attention of Mr. A. B. Wynne,[1] Dr. H. Warth,[2] Mr. B. H. Powell,[3] and others.

The crystals are found embedded in the gypsum near Marí, at the western end of the Salt Range; Kálábágh, on the west side of the Indus; and at Sardi, Kusak and Katha in the Salt Range. They weather out from their soft and partly soluble matrix in a manner which at once arrests the attention of the observer from the brilliant lustre of the crystal-facets.

Physical characters.

In size they vary from that of a millet-seed to that of a walnut; in colour from white, through shades of pink, to brick-red. They are often transparent on the exterior, but in the centre of each crystal there is invariably a white or pink translucent core. In some cases, where the inclusions are of sufficient dimensions, the light reflected from their faces produces an avanturine appearance. The suspicion that these translucent cores might be due to inclusions of the matrix led me to expect that a careful investigation of the specimens might afford some evidence as to their origin and their decidedly remarkable form and mode of occurrence.

Crystalline form.

The crystals almost invariably present combinations of the hexagonal prism and pyramid.[4] Of over three hundred which I have examined, I failed in three cases only to detect a development of the prism form. Their bi-pyramidal nature and comparative regularity of their faces recall at once the quartz of like form found in many acid volcanic rocks, where a yielding liquid magma has probably allowed a symmetrical development of the faces. Mr. Middlemiss has remarked that crystals so perfect and exhibiting no trace of rounding are certainly not characteristic of sub-aerial sedimentary formations; and their occurrence, therefore, in gypsums, which are generally regarded as aqueous in origin, is a fact worthy of notice.

The prism-faces in these crystals are almost invariably pitted and marked, but in the absence of any definite shape to these markings it is impossible to say whether the blemishes are due to "etching."

[1] *Mem. Geol. Surv., Ind.*, vol. xiv (1878), pp. 13, 180, 268 and 300.

[2] *Inland Customs Administration Report*, 1870-71. "Report on the Salt Mines of the Punjáb Salt Range west of Pind Dadun Khán." Appendix D, p. 189.

[3] Handbook of Punjáb Economic Products (1868), pp. 41, 48, 59.

[4] Mallet. *Manual, Geol. Surv., Ind.*, vol. iv (1887), p. 65; Plate III, Figs. 17— 2.

Cleavage.

Specimens dropped into a platinum crucible previously raised to a white heat invariably become traversed with cracks, and pieces frequently fly off. In this way I have, in a few cases, developed the rhombohedral cleavage of quartz with a lustre of cleavage-face sufficiently perfect to allow of measurement with the reflecting goniometer, the results agreeing so closely with the angle for *R.* as to leave no doubt about the form.

Fracture.

Crystals, when broken, exhibit a fracture whose surface is composed of a series of zonal ridges and furrows. This is the case both with fractures at right angles and parallel to the vertical axis, and a corresponding zonal arrangement of inclusions is sometimes seen in thin slices under the microscope.

Microscopic characters.

Finding from a preliminary qualitative analysis that sulphate of lime in some form existed in the crystals, sections were made by grinding in oil instead of in water. Under the microscope the centres of the quartzes are seen to be crowded with small plates (of less than ·35 mm. edge) of a colourless and highly doubly refracting mineral in approximately square or irregularly-shaped plates, which, on chemical examination, proved to be *anhydrite* (Plate I, Fig. 2). The anhydrite-crystals seldom exhibit cleavage-cracks and never, as far as I have observed, any twinning. In the centres of the quartzes they often exceed their host in bulk; but towards the exterior the fragments are more widely separated from one another, and there is generally an external border of clear quartz.

Inclusion of anhydrite in quartz.

Chemical analysis.

I selected three crystals for chemical examination, having previously determined the specific gravity of each specimen.[1] The following results have been obtained:—

	I.	II.	III.
Specific gravity	2·742	2·692	2·687
Chemical analysis:			
Silica	70·02	86·77	87·55
Alumina	tr.	...	...
Ferric oxide	·02	tr.	...
Lime	12·21	5·35	4·98
Magnesia	tr.	...	...
Sulphuric acid	17·44	7·65	7·12
Loss on ignition	·28	·20	·15
	99·97	99·97	99·80

Neglecting the loss and impurities, which are very small, and calculating the results to 100, we obtain a mineralogical composition of—

	I.	II.	III.
Quartz	70·25	86·96	87·85
Anhydrite	29·75	13·04	12·15
	100·00	100·00	100·00

[1] The method employed in determining the specific gravity I hope to describe in a succeeding note. For the present it is safe to say that the limit of accuracy in these results is well within ·001 (sp. gr.).

Taking the average specific gravity of quartz to be 2·65 and that of anhydrite to be 2·95, we may calculate the theoretical specific gravity of a mixture of these two minerals in the proportion obtained by analysis. The following results are thus obtained :—

	I.	II.	III.
Specific gravity *calculated* . . .	2·740	2·690	2·688
" " *determined* . . .	2·742	2·692	2·687

In these three specimens there is, therefore, no difference greater than ·002 between the specific gravity actually determined and that calculated from the chemical analysis of the same specimen. These results leave no doubt as to the accuracy of the chemical analyses, and as to the condition in which the sulphate of lime exists in the quartz.

It is possible then to determine, within a small range of accuracy, the chemical and mineralogical composition of a specimen from its specific gravity. To this end I have determined the specific gravity of eight other specimens of bi-pyramidal quartz-crystals; calculating the mineralogical composition, the following results are obtained :—

		IV.	V.	VI.
Specific gravity (determined) . . .		2·743	2·720	2·700
Mineralogical composition (calculated)	Quartz .	69·00	76·67	83·33
	Anhydrite .	31·00	23·33	16·67
		100·00	100·00	100·00

		VII.	VIII.	IX.
Specific gravity (determined) . . .		2·696	2·695	2·694
Mineralogical composition (calculated)	Quartz .	84·67	85·00	85·34
	Anhydrite .	15·33	15·00	14·66
		100·00	100·00	100·00

		X.	XI.
Specific gravity (determined)		2·694	2·688
Mineralogical composition (calculated)	Quartz . . .	85·34	87·34
	Anhydrite . . .	14·66	12·66
		100·00	100·00

I have found no specimen with a specific gravity less than 2·687 (No. III), which corresponds to an inclusion within the quartz of 12·15 per cent. of anhydrite. No. IV possesses the highest specific gravity of the specimens I have determined (2·743). This gravity represents an inclusion of 31 per cent. of anhydrite.[1]

Conclusions.

The occurrence of anhydrite included in quartz-crystals has not, so far as I am aware, been hitherto recorded, and considerable interest is attached to this occurrence from the fact of these crystals

[1] The last eight specimens were successively precipitated from suspension in Sonstadt's iodide-solution by gradual dilution. The specific gravities are thus obtained in descending order.

occurring in a matrix of gypsum. We have thus specimens of the sulphate of lime, in the condition in which it existed at the time of the formation of the quartz, sealed up and preserved for our examination, whilst the masses around have been hydrated to gypsum and in other respects changed in chemical and physical characters.[1] There seems to be no doubt that *the sulphate of lime was in the anhydrous condition at the time of the genesis of the quartz-crystals.*

From the constant bi-pyramidal, and comparatively symmetrical, character of the crystals it might be expected that the sulphate of lime must have been in a condition to allow of freedom of growth in all directions, and such a condition could scarcely be conceived to be the case in a rock of the same hardness and crystalline character as massive anhydrite.

From the manner in which sulphate of lime absorbs water to form gypsum, we may conclude that the quartz-crystals could not have been deposited from water at any temperature below 100° Cent., otherwise the inclusions would have contained over 20 per cent of water, or from about 2·5 to 6·3 per cent on the whole crystal. If the lime-sulphate previously existed in the hydrated condition the temperature must have been raised at least to 200° Cent., the temperature at which gypsum yields its last molecule of water *at the ordinary atmospheric pressure.* An increase in the superincumbent pressure (it is not likely to have been below normal) would imply a still higher temperature.

Professor W. R. Johnson has described a specimen of hydrated sulphate of lime $2CaSO_4, H_2O$, occurring with a fibrous structure in the crust formed in marine boilers worked at high pressure, in which the temperature could not have been less than 150° C.,[2] and F. Hoppe-Seyler has shown that the same compound can be produced by heating pulverised gypsum and water in sealed tubes to 140°—160° C.[3] I think we shall not be far from the truth if 200° Cent. be taken as the *lower limit of the temperature* at which the quartz-crystals could have been formed. With regard to the *higher limit*, the controlling facts to be considered are (1) the temperature at which sulphate of lime loses its sulphuric anhydride, and (2) the possible action of fused sulphate of lime on quartz.

Concerning the action of heat on calcic sulphate Fresenius[4] quotes the experiments of Al.Mitscherlich, which showed that sulphate of lime, heated to an intense red heat, fuses and loses weight considerably from loss of sulphuric acid,[5] whilst Boussingault says that the whole of the sulphuric anhydride escapes at a white heat.[6] I have been unable to see these two papers; but I find on repeating the experiments that pure sulphate of lime does not lose weight at a cherry-red heat and shows no signs of fusion. When mixed with silica, however, there is considerable loss at that temperature. Heated to a white heat, the pure sulphate loses sulphuric acid considerably; but I have seen no signs of fusion *after* the heating probably on account of the formation of lime.

[1] That the matrix in which the quartz-crystals are embedded has been changed *to* gypsum *from* anhydrite I shall show in the sequel to be the case from the chemical and microscopic characters of so-called gypsums of the Márí and other areas.

[2] *Amer. Journ. Sci.*, ser. II, vol. v (1848), p. 113.

[3] Poggendorf's *Annalen*, vol. cxxvii (1866), p. 161.

[4] Quantitative Chem. Anal., 7th Ed. (1876), vol. i, p. 121.

[5] *Journ. für Prakt. Chem.*, vol. lxxxiii, p. 485.

[6] *Zeitschr. f. Anal. Chem.*, vol. vii, p. 244.

On exposing for some time to a white heat a specimen of the bi-pyramidal quartz-crystals *in its gypseous matrix*, the lustre of its faces was completely destroyed and the crystal exhibited all the signs of having been etched.

These facts do not, I think, favour the supposition of the anhydrite being in a fused condition at the time of the formation of the quartz. Bischof ridicules the notion that quartz could exist unaffected in the presence of fused anhydrite, and considers the often suggested igneous intrusion of sulphate of lime as "a mere reverie emanating from the Plutonic school!"[1]

It seems to me to be more nearly in agreement with the facts to suppose that the quartz-crystals in the gypsum of Márí have been deposited at high temperatures from, most probably, super-heated water.

It follows, also, from the above facts that the *quartz-crystals are younger than the anhydrite, older than the gypsum, and must have been formed in their present position.* There is not a trace of evidence in favour of their having been rolled in water or in any other way subjected to sub-aerial agencies. I shall have occasion to recur to this last point in discussing the evidence obtained in examining the gypseous matrix, and which seems to lend no support to the supposition that the gypsum of the Márí and Kálábágh areas, at least, are of immediate sedimentary origin. So far as I am able to understand the conclusions to which Mr. Middlemiss has been led by an examination of the characters of these formations in the field, the evidence obtained in the laboratory is not, so far, inconsistent with his hypothesis concerning the origin of the gypsums and marls of the Salt Range.

II.—*On the Conversion of Anhydrite into Gypsum.*

The interesting occurrence of anhydrite in the bi-pyramidal crystals of quartz naturally suggested an examination of the gypseous matrix in which the crystals are found.

Some of the specimens collected in the Salt-Range are very variable in composition, having become impregnated with large quantities of carbonate of lime and magnesia, as well as argillaceous material. Others are almost pure gypsum; but two specimens from the Márí area, collected by Mr. Wynne, were noticeably harder and more crystalline than the usual type of quartz-bearing gypsums. On ignition I found a sample of one of these to contain only 4·16 per cent. of water instead of 20·95—the percentage of water in pure gypsum. A fragment balanced in Sonstadt's iodide-solution gave a specific gravity of 2·821. Subsequently I discovered that fragments from different parts of the same specimen varied in specific gravity, and also in the amount of water yielded on ignition. In consequence of this variation in the hydration, I selected small fragments, weighing about 2 grammes each, and determined their specific gravities one by one; *the whole fragment* was then crushed to a powder for analysis. In this way the specific gravity and the chemical composition of a fragment could be compared with one another as already described in the case of the quartz-crystals. This method has been adopted uniformly throughout the whole of the results recorded in the sequel, and all determinations made before adopting this precaution have been rejected.

[1] *Lehrbuch der chem. und phys. Geol.*, Bonn, 1864; vol. ii, p. 194.

According to Mr. Wynne, true anhydrite has never been found associated with the gypsum of the Salt Range, but large nodular cores of greater weight and hardness and of a bluish white tint occur within beds of gypsum. Specimens of this rock were found by Dr. Warth to contain 5 per cent. of water and termed *semi-anhydrite*.[1]

Anhydrite and "Semi-anhydrite" of Warth.

The discovery by Dr. Warth of the low percentage of water in these nodules, led me to a more detailed examination of the causes which have produced similar peculiarities also in the matrix of the quartz-crystals at Márí. Mr. Wynne, on the same page of his memoir, refers to the fact that at high temperatures and under pressure, sulphate of lime crystallizes with 6·21 per cent. of water; and I have already quoted Professor Johnson's discovery of this compound as a constituent of marine-boiler crusts (*ante*, p. 234). I have stated below the facts which show the presence of undoubted *anhydrite* in the specimens collected by Mr. Wynne, and the reasons which lead me to believe that up to the present, at least, no distinct compound between $CaSO_4$ and $CaSO_4$, 2 H_2 O has been found in the gypsums of the Salt Range.

If the term semi-anhydrite was intended to represent a distinct species or variety no support for the notion can be obtained from the typical specimens in the Museum collected from the Mayo mines. All cases which I have examined are merely mixtures in varying proportions of anhydrite and gypsum. This being the case, the specific gravity of a fragment can be calculated from its chemical composition, and *vice versâ*. To what degree of accuracy this is possible may be seen from the results stated below. The specific gravity of any fragment may be stated as—

$$G = \frac{x. \text{ Gypsum} \times 2{\cdot}32 + y. \text{ Anhydrite} \times 2{\cdot}95}{x + y}.$$

In the same way having determined the specific gravity the mineralogical composition is found thus— (x = percentage of Anhydrite).

$$G = \frac{2{\cdot}95\, x + (100 - x)\, 2{\cdot}32}{100}$$

or—

$$\cdot 63\, x = (G - 2{\cdot}32)\, 100.$$

From this result—

$$(100 - x) \times \cdot 2095 = \text{percentage of water.}$$

Besides the complete analysis of typical specimens I have estimated the water and determined the specific gravities of numerous fragments, comparing the calculated with the actual result according to the above formulæ.

In the specimens described as containing 5 per cent. of water, I have never obtained a fragment yielding less than 9·15 per cent. But I have, however, found specimens labelled "gypsum" which contain as little as 4·02 per cent. of water.

[1] Wynne. *Mem., Geol. Surv., Ind.*, vol. xiv (1878), p. 74.

The following are the details of these results[1]:—

(1) Matrix of the quartz-crystals, Márí (Museum No. $\frac{8}{83}$):—

Specific gravity—2·820.

Chemical analysis:

	Water	4·02
	Lime	39·20
	Sulphuric acid	56·12
Impurities .	Ferric oxide	tr.
	Magnesia	·33
	Silica[2]	·12
		99·79

Omitting the impurities, combining the lime and sulphuric acid, and calculating to 100 we obtain—

Sulphate of lime	95·95
Water	4·05

This corresponds to a mineralogical composition of—

Anhydrite	80·67
Gypsum	19·33
	100·00

Adopting the formula given above for calculating the specific gravity we obtain—

$$\frac{80·67 \times 2·95 + 19·33 \times 2·32}{100} = 2·828.$$

The actual specific gravity of the fragment was, according to experiment, 2·820. Results so closely agreeing as these may be taken as strong evidence that the hard variety of the "gypsum" containing the quartz-crystals is merely a *mixture* of the two minerals—gypsum and anhydrite.

In consequence of the comparative purity of the rock, I have determined the specific gravities of two other fragments, calculated the mineral composition as in the case of the quartz-crystals, and, for comparison with the theoretical, estimated by ignition the actual percentage of water in each piece.

(2) Specific gravity: 2·817 (*determined.*)

Mineral composition.		Chemical composition. (*calculated.*)		Water. (*determined.*)
Anhydrite .	78·88	$CaSO_4$	95·58	......
Gypsum .	21·12	H_2O	4·42	4·23
	100·00		100·00	

[1] In each of these determinations the specific gravity of a selected fragment is, as stated before, first determined, and *the whole fragment* subsequently used for chemical analysis.

[2] In the form of minute quartz-granules.

(3) Specific gravity: 2·824 (*determined.*)

	Mineral composition.	Chemical composition. (*calculated.*)		Water. (*determined.*)
Anhydrite .	80·00	Ca SO_4	95·81	......
Gypsum .	20·00	H_2O	4·19	4·02
	100·00		100·00	

It will be noticed that in each case the water actually found was less than the calculated percentage. This is probably due to impurities in the specimen. The same remark applies to the results of all other cases enumerated below.

In a similar manner I have investigated the specimens collected from the Mayo mines and containing, according to Dr. Warth's analyses, 5 per cent. of water ("semi-anhydrite").

Five fragments were cut from different parts of the specimen (M. 2627), and the specific gravity of each fragment determined. One, possessing a medium specific gravity, was selected for chemical analysis. In the remainder only the water was estimated—

(1) *Specific gravity:* 2·523.

Chemical composition:

	Water	13·16
	Lime	35·27
	Sulphuric acid	50·96
Impurities .	Carbonic acid	·35
	Ferric oxide	·24
	Magnesia	·31
		100·29

A mixture of gypsum and anhydrite with a specific gravity of 2·523 possesses theoretically a composition of—

	Mineralogical composition.	Chemical composition.	
Anhydrite .	67·78	Ca SO_4	85·81
Gypsum .	32·22	H_2O	14·19
	100·00		100·00

By comparing these results with those obtained by analysis it will be found that the differences are no greater than can be accounted for by the presence of impurities.

The following results were obtained for the remaining fragments:—

	Sp. Gr. (*determined.*)	Composition. (*calculated.*) Mineralogical.		Chemical.		Water. (*determined.*)	Diff.
		Anhydrite.	Gypsum.	Ca SO_4	H_2O		
No. 2 . . .	2·421	16·03	83·97	82·41	17·59	16·80	0·79
No. 3 . . .	2·628	48·89	51·11	89·29	10·71	9·15	1·56
No. 4 . . .	2·474	24·44	75·56	84·17	15·83	Lost.	...
No. 5 . . .	2·470	23·80	76·20	84·04	15·96	15·07	·89

Nos. 2 and 3 are examples of the wide variation in composition in different parts of the same hand-specimen. By Mohr's method I determined the specific gravity of the whole specimen and found it to be 2·472. From this specific gravity one may, with a fair degree of accuracy, estimate its mineralogical and chemical composition thus:—

Anhydrite	24·11	Sulphate of lime	84·09
Gypsum	75·89	Water	15·91
	100·00		100·00

A second specimen from the same locality and labelled also "semi-anhydrite" offers evidence of the same nature (No. $\frac{5}{61}$).

A chemical analysis gave the following results:—

Water	13·25
Lime	35·68
Sulphuric acid	51·01
Carbonic acid	undetermined.[1]
Ferric oxide	·23
Magnesia	·31
	100·48

Specific gravity: 2·511.

The specific gravity (2·511) corresponds theoretically to—

Sulphate of lime	85·40
Water	14·60
	100·00

a result not widely differing from the analysis given above.

The specific gravity of the large hand-specimen determined by Mohr's method proved to be 2·523. The average mineral composition, therefore, is approximately—

Anhydrite	32·22
Gypsum	67·78
	100·00

corresponding to—

Sulphate of lime	85·80
Water	14·20
	100·00

These results differ very widely from those obtained by Dr. Warth; but I am unable to find any source of error which can account for the very great discrepancy

[1] The carbonic acid existed in very small quantities, and its actual estimation would be of little value compared to the additional time it would occupy.

between our analyses. Dr. Warth has unfortunately omitted to give the details or number of the analyses by which he obtained an average of 5 per cent. of water in these rocks.[1]

Anhydrite from Spiti.

In order to investigate still earlier stages in the hydration of calcium-sulphate, I made a similar examination of the massive anhydrite collected by Mr. F. R. Mallet in the Spiti valley, North-West Himalayas. Portions of these specimens contained cleavable anhydrite, which on analysis confirmed Mr. Mallet's determination, cleavage-fragments giving an average specific gravity of 2·949.

Two fragments, however, selected from the granular part of the specimen showed the earlier stages of hydration. Having determined the specific gravity of both pieces I estimated the water in one and made an analysis of the other.

The first piece had a density of 2·846 and contained 3·37 per cent. of water. The calculation from the specific gravity gives a composition of—

Anhydrite	83·49	$CaSO_4$	96·55
Gypsum	16·51	Water	3·45
	100·00		100·00

The specific gravity of the second fragment was 2·832, and on chemical analysis I obtained the following result:—

Water	3·66	
Lime	39·59	} $CaSO_4$ = 95·93.
Sulphuric acid	56·34	
Carbonic acid	tr.	
Ferric oxide	tr.	
	99·59	

From the specific gravity the composition should be—

Anhydrite	81·27	$CaSO_4$ =	96·08
Gypsum	18·73	H_2O =	3·92
	100·00		100 00

results very closely agreeing with those obtained on analysis.

Microscopic structure.

The close agreement existing between the specific gravity and chemical composition in each case leaves little doubt as to the nature of these rocks, but the results are confirmed in the most striking manner by the microscopic characters of thin sections.

On account of the solubility of gypsum in water I at first attempted to cut the sections in oil; but this substance would not permit of the reduction of a rock so soft and friable to sections sufficiently thin. At last I found the use of a concentrated solution of sulphate of lime allowed of the most satisfactory results.

[1] Since writing the above, Dr. Warth has very kindly offered to send me his *typical* specimen to which Mr. Wynne referred as "semi-anhydrite." On its arrival, I hope to subject this specimen to a similar investigation as to its chemical and physical characters; the results will appear in the next number of the Records.

A large number of sections examined under the microscope show every gradation from the massive part of Mr. Mallet's Spiti specimens, in which large crystals of anhydrite are cemented with mere films of gypsum polarising with characteristic colours of the lower orders, through others in which the gypsum assumes a larger proportion and ultimately makes up the entire field.

Ophitic structure.

In the earlier stages hydration has developed gypsum along cleavage-cracks and twinning planes. In the specimens from the Mayo mines gypsum stretches across the field in large irregular plates, including numerous crystals of anhydrite, and exhibiting a constancy of orientation over considerable areas. This structure at once recalls the ophitic structure so common in the doleritic rocks, although it is entirely different in origin, being, in this rock, a secondary structure due to hydration. The gypsum-crystals sometimes exhibit lamellar twinning running across these ophitic plates and regardless of the included anhydrite (Plate I, Figs. 1 and 4). The clear gypsum and the bent lamellæ forcibly recall in appearance the fresh plagioclase-felspars of igneous rocks (Plate I, Fig. 4).

Expansion of the mass.

Schistose structure.

The hydration of sulphate of lime to gypsum is accompanied by an expansion in the mass of nearly 30 per cent. These changes can be followed in the microscope. Cases are found in which the formation of gypsum in a cleavage-crack has given rise to a slight angular displacement of the cleaved fragment (Plate II, Fig. 1). Faulting of twinning and cleavage-planes arises from the same cause. These changes can be traced to a rock in which crystals are fractured and the fragments scattered along lines to produce a distinctly foliated structure—a self-induced schistosity—a structure observable even in the hand-specimens collected from the Mayo mines (Plate I, fig. 3). The expansion which has produced such changes in the internal structure of these rocks must have been an important factor in the causes which led to the stratigraphical disturbances in the super-incumbent beds.

Microscopic characters of anhydrite.

The anhydrite occurs in crystals in which two pinacoidal cleavages are always noticeable, one frequently more perfect than the other. In thin slices the colours are always bright and seldom as low as the first order. With convergent polarised light the bi-axial figure is often obtained, but the wide optic-axial angle prevents a reliable determination of the dispersion. The results I obtained appeared to be $\rho < \nu$. The positive character of the double refraction is easily determined.

Twinning of anhydrite.

A noticeable feature in all the specimens is the distinct lamellar twinning, which appears to be parallel to the brachydome of Dana, $1-\breve{\imath}$.[1] (See Plate II, Figs. 2 and 3.) The regularity of the cleavage planes and twinning is shown in the case figured, in which the two sets of twinning planes are easily noticeable. The pressure to which the rock has been subjected and the consequent production of gliding planes in the crystals is illustrated in Plate II, Fig. 4. The centre of crushing seems to have been at the point A, where an irregular mosaic of broken crystal-fragments has been produced, and the crystal has yielded along the gliding planes shown in the sketch.

[1] Dana reads the axes in a different order to that adopted by Rosenbusch. According to the former author the acute bisectrix is perpendicular to the basal plane and the optic-axial plane lies in $i-\bar{\imath}$.

Hydration of anhydrite.

Taken with the chemical and other characters the microscopic examination of these rocks leaves little doubt that the anhydrite has, by the absorption of water, recrystallized as gypsum. These specimens do not offer the faintest evidence in favour of the notion that a compound between Ca SO_4 and Ca SO_4, 2 H_2O exists with specific characters.

It would not be surprising to find that many of the large masses of the so-called anhydrite-rock of Nova Scotia, Switzerland and other places prove on microscopic and chemical examination to be mixtures of sulphate of lime, anhydrous and hydrous. Professor How, in an interesting series of papers on the mineralogy of Nova Scotia, considers that the masses of anhydrite-rock exposed in the Gut of Canseau, between Nova Scotia proper and Cape Breton, have originated independently of the associated gypsum, and doubts the formation of gypsum from anhydrite.[1]

K. von Fritsch, however, has shown that the gypsum of Airolo and Val Canaria has been produced from anhydrite with an accompanying increase in bulk and consequent disturbance of the adjacent rocks, in which minerals as hard as quartz are crushed and bent by the pressure.[2]

Origin of the Salt Range gypsum.

There is no doubt, I think, that the gypsum of the Salt Range in areas so widely separated as Khewra and Márí as well as at Kálábágh, west of the Indus, has been the result of the alteration of anhydrite; and the production of this latter mineral by deposition from water at ordinary temperatures cannot be conceived to be possible. The evidence, therefore, of the laboratory is distinctly against the supposition that the gypsum in these areas, at least, has been produced by the evaporation of water containing sulphate of lime. That this conclusion applies in general to the whole of the gypsum-deposits in the Salt Range I do not assert; but it is worthy of remark that the localities have in no way been selected and are widely separated. This conclusion, moreover, coincides precisely with the facts obtained by Mr. Middlemiss during a recent examination of the rocks in the field, and recorded by him in the paper already quoted.[3] Mr. Middlemiss, whilst denying the aqueous origin of the salt-marl, suggests that it might be traced to the action of subterranean forces, the precise nature of which the facts so far obtainable in the field are insufficient to determine.

Concerning the gypsum of Nova Scotia, Sir William Dawson has suggested that its origin might be due to the action of volcanic waters containing sulphuric acid on limestones; but he cannot thus account for the intermixed anhydrite.[4] Professor How's discovery of boron-bearing minerals in these rocks confirms, in his opinion, Dawson's theory.[5]

There seems to be no reason why a somewhat similar action might not have taken place on masses of limestone in the Salt Range area. Under pressure and at a high temperature anhydrite would be produced, and subsequent hydration of the mass—

[1] *Phil. Mag.*, vol. xxxvi (4th Ser., 1868), p. 40. See also— *Phil. Mag.*, vol. vii (1857), pp. 54—60; vol. xiv (1861), pp. 112—116, and vol. xxxv (1868), pp. 32 and 218.

[2] *Jahrb. für Min.*, vol. vii, p. 299.

[3] *Rec., Geo. Surv., Ind.*, vol. xxiv (1891), pp. 19—47.

[4] Acadian Geology, 2nd Ser. (1868), pp. 261, 262 and 394.

[5] *Amer. Journ. Sci.*, 2nd Ser., vol. xxxii (1861), p. 13.

which undoubtedly has occurred—would give rise to gypsum.[1] The presence of the marl and salt, I hope to show, offers no objection to this explanation; but simply accounts for the aluminous silicates of the alkalies which existed in the original rock masses.[2]

The facts obtained so far in the examination of these rocks confirm the conclusions suggested by the quartz-crystals; and both agree with the evidence obtained in the field. It would not be surprising to find on more careful search in this area minerals containing boracic acid.

Summary of conclusions. From the study of the specimens the following conclusions have suggested themselves to me:—

1. That the gypsum-masses are not of aqueous or sedimentary origin.
2. That they are formed by the addition of water to anhydrite.
3. That the quartz-crystals were formed at a period anterior to the hydration, but after the formation of the anhydrite.
4. That the anhydrite may have been produced by the action of sulphuric acid on limestone, the action probably taking place at a high temperature and in the presence of super-heated waters, in the manner in which many igneous rocks have been altered by solfataric action subsequent to their primary consolidation.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Section of "gypseous" matrix of the bi-pyramidal quartz-crystals. Composed of *anhydrite* exhibiting pinacoidal cleavage and lamellar twinning (in two crystals); and *gypsum* in one large crystal ophitically developed around the anhydrite with repeated twinning. From Márí, North-West Punjáb. Magnified × 143 diameters. (See p. 241.)

Fig. 2. Horizontal section of a bi-pyramidal crystal of quartz, showing anhydrite included in small crystals which are, towards the edge, arranged in zonal lines. From Márí. Magnified × 143 diameters. (See p. 232.)

Fig. 3. A rock composed of gypsum and anhydrite, the latter in small crystals drawn out to form a schistose structure. From the Mayo mines, Khewra, (so-called "semi-anhydrite"). Magnified × 143 diameters. (See p. 241.)

Fig. 4. Section from the same specimen as Fig. 1. The lamellæ of gypsum are bent.

PLATE II.

Fig. 1. Crystal of anhydrite, the fragments of which have suffered a slight angular displacement (2°) by the development of gypsum between the pieces.

[1] It is interesting to note that Mr. Mallet has long ago suggested that the gypsum of the Spiti valley has been due to thermo-aqueous agencies (Mem., Geo. Surv., Ind., vol v. (1866), p. 157). I have already shown that the earlier stages of hydration of the sulphate of lime are present in the massive anhydrite collected by Mr. Mallet in the Spiti area (*ante*, p. 240).

[2] The presence of the Khewra trap in the salt-marl remains as the solitary proof that undoubted igneous action has taken place in this area.

From the matrix containing bi-pyramidal crystals of quartz, Márí. Magnified × 310. (See p. 241.)

Fig. 2. Crystal of anhydrite showing cleavage and twinning. T, T′ and T″ are twinned patches in which the cleavage lines and optical characters are at an angle to those in the general mass of the crystal. The directions of these lines are shown in the diagram (Fig. 3). From massive anhydrite, Spiti valley, North-West Himalayas. Magnified × 310. (See p. 241.)

Fig. 3. Diagram showing the directions of the cleavage and twinning lines of the specimen shown in Fig. 2.

OA, OD = directions of pinacoidal cleavage. OD = most perfect, lying in the plane of the axis of minimum optical elasticity.

OC, OF = traces of gliding planes.

T, T′, T″ = twin-lamellæ in which the cleavage parallel to OB (the most perfect) corresponds to OD of the remainder of the crystal, and OE, the other pinacoidal cleavage, corresponds to OA (least perfect). The angles are shown in the figure.

Fig. 4. Crystal of anhydrite showing the two directions of twinning with gliding planes produced by pressure the centre of which coincided with A. From the massive anhydrite of Spiti, North-West Himalayas. Magnified × 310. (See p. 241.)

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 9.—Ending 31st October 1891.

Director's Office, Calcutta, 31st October 1891.

The staff of the Survey is being distributed as follows :—

Lower Burma.—Theo. W. Hughes Hughes, A.R.S.M., Superintendent.
P. N. Bose, B.Sc., 2nd Grade Deputy Superintendent.

Upper Burma.—C. L. Griesbach, C.I.E., Superintendent.
Fritz Noetling, Ph.D., Palæontologist.
P. N. Datta, B.Sc., Assistant Superintendent.

Bengal.—T. D. LaTouche, B.A., 2nd Grade Deputy Superintendent.

Punjab.—C. S. Middlemiss, B.A., 2nd Grade Deputy Superintendent.
W. B. Dallas Edwards, A.R.C.S., Assistant Superintendent.
Sub-Assistant Hira Lal.

Fig 1 × 143

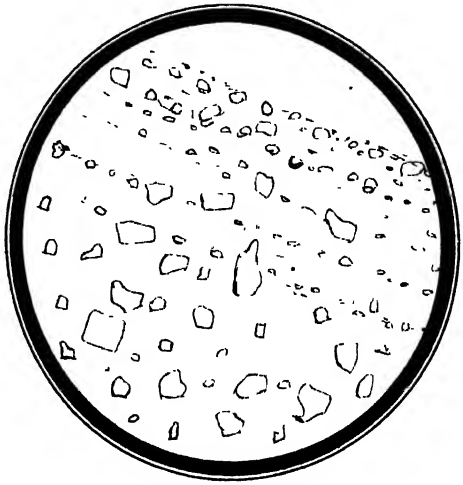

Fig 2 × 143.

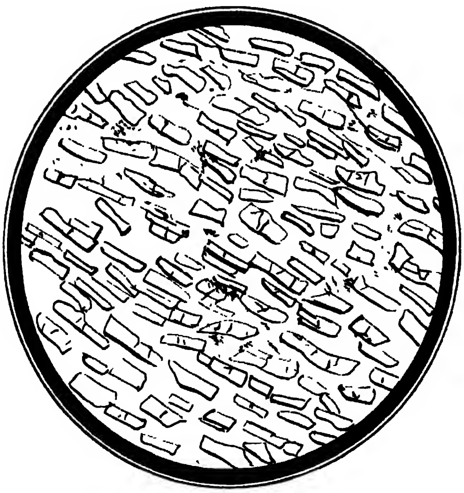

Fig 3 × 143

Fig 4 × 143

T.H Holland del et lith

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PLATE. I

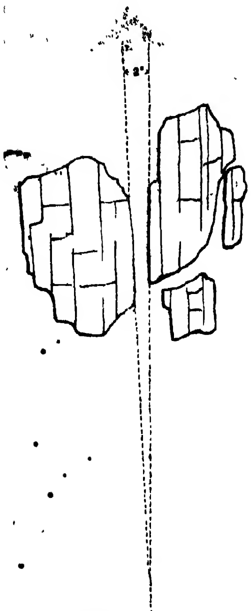

Fig 1 × 310

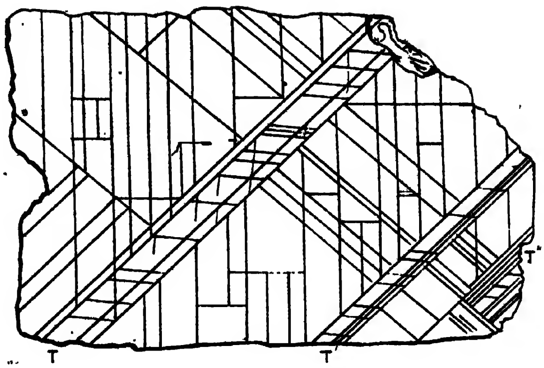

Fig. 2 × 310.

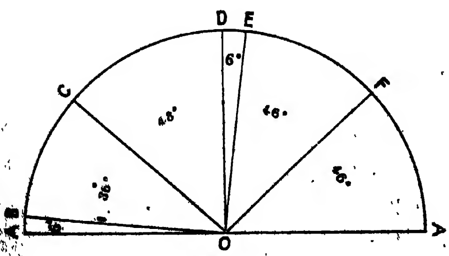

Fig. 3

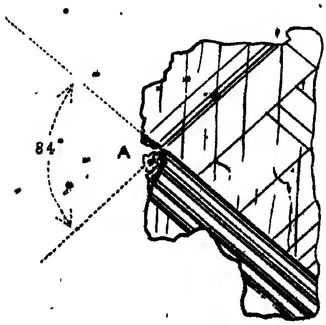

Fig. 4 × 310.

T. H. Holland del. et lith. Printed at Geol. Surv. Office.

PLATE. II.

Head-Quarters, Calcutta.—The Director.

R. D. OLDHAM, A.R.S.M., 1st Grade Deputy Superintendent.

T. H. HOLLAND, A.R.C.S., Assistant Superintendent.

Mr. Oldham is engaged in the preparation of the Manual of the Geology of India: Mr. Holland is in charge of the Museum and Laboratory, but will be deputed during part of the field season for the collection of a series of specimens and notes illustrative of iron in India, especially in connection with the requirements of the Imperial Colonial and Indian Institute. Sub-Assistant Kishen Singh will accompany Mr. Holland.

The Director was on tour from the 3rd of September to the 23rd of October at Madras, in the Salem and Kurnool Districts, at Hyderabad, Ahmedabad, Ajmere, the Mohpani Colliery, and in the Punna State. At Madras, owing to the impending retirement of Mr. Foote, a scheme was arranged with Dr. Warth, at present transferred from the Survey as Officiating Superintendent of the Government Central Museum, to carry on geological research during the collecting tours organized in that Institution. At Salem, the revived question of the leasing and development of the enormous iron-ore tracts in that district, which has now been dormant for over a quarter of a century, principally through the paucity of wood-fuel and burdensome transport rates, is to be assisted by Mr. Holland's iron enquiry during the next field season. It having been reported by the district officials that the steatite mines of Betumcherla, in the Kurnool District, did not appear to be capable of yielding the small quantity of fine stone (locally called "bulpum") of the block-dimensions asked for by the manufacturers of gas burners in London, a visit was paid to these mines. The thicknesses of the beds are, as a rule, too small to allow of 6-inch cubes, though there is some cause for assuming that the limit of cube laid down may have been given at random, considering the small size of the articles manufactured; but there is no doubt that plenty of the stone, thin as it is, is obtainable under a better method of mining than the irregular grubbing excavation pursued by the local miners. At Ahmedabad, Mr. H. E. M. James, then Commissioner of the Northern Division, re-opened the question last year of a possible improvement of the water-supply of the district by resorting to artesian boring; but opportunity could not be arranged until the present tour for taking it up further than had been done in the discussion by the previous Director (Mr. Medlicott) in 1885, that is, by personal inspection of the country. The conditions of uncertainty continue as stated by Mr. Medlicott, but there are grounds for expecting a rather larger supply of deep percolating sub-alluvial water than he calculated on, though there is no knowing whether it will be sweet, or that it will rise to a sufficient height in the wells. It is after all little more than a matter of chance, and exceedingly much a matter of cost; but an estimate is being made of the probable amount of the latter, with a view to deciding whether an arrangement can be made for an experimental boring in the neighbourhood of Viramgaum, where it is understood that the greatest difficulty is apprehended in keeping the present ordinary wells from becoming too brackish. At Ajmere, a similar request as to artesian possibilities had been received from Captain de Lassöe, the District Magistrate; but an inspection showed that there is no hope in that direction, there being no alluvial tracts of any extent, while the stratigraphy of the proper rock-series is entirely against it. At the Mohpani Colliery, the deep boring, for which certain rebatements in royalty had been allowed by the Central Provinces Government, is now being shoved on with renewed vigour, the Narbudda Coal and Iron Company having imported an American portable steam-boring machine, which so far, but only after some slight modification of the handling gear, and training of the men, seems to be running most satisfactorily—a result which is most cheering after the disappointing experiences reported concerning the working of the Survey machine at the late Daltonganj coal-field boring exploitation. At Punna, H. H. the Maharajah was advised as to the extent of the mineral resources of his State.

Mr. R. Bruce Foote, Senior Superintendent of the Survey, retired from the service on the 30th September, after a long and distinguished career of over thirty-three years, two of which were on extension of service. It is, however, most gratifying to know that his geological work in India does not close thus, his services having been secured by the Baroda State for the closer determination of its mineral resources.

Mr. W. B. Dallas Edwards, Associate of the Royal College of Science, London, joined the Department on the 20th October, as Assistant Superintendent, 3rd Grade.

List of Reports and Papers sent in to Office for publication or record during August, September, and October 1891.

Author.	Subject.	Disposal.
T. W. H. Hughes . .	Tin-Mining in Mergui District, Part III.	Record.
P. N. Bose	1. Darjeeling Coal Exploration. 2. Geology of Sikkim.	Appear in the current Records, Geological Survey of India.
C. S. Middlemiss . .	1. Microscopical examination of Salt-Range Boulder-bed rocks. 2. Progress Report for 1890-91.	To appear in the next Records. Record.
P. N. Datta.	The Rongrengiri Coal-field, Garo Hills	Record.
T. H. Holland . . .	1. Work done in the Laboratory, Geological Survey of India. 2. Chemical and Physical Notes on Rocks from the Salt-Range.	Appear in the current Records, Geological Survey of India. "

Report *on the* Work *done in the* Laboratory *of the* Geological Survey of India *during the months of* August, September, and October 1891, *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Geological Survey of India.*

In addition to the results obtained in the examination of the rocks from the Salt Range, published as a separate note in this part of the Records, a number of assays and determinations of specimens have been made of ores, oils, and other substances. A list of these is given below :—

1. Brines from the Sambhar Lake, Rajputana.

The following preliminary report embodies the results of my examination of four samples of brine and one sample of dry residue collected in March last from the Sambhar Lake, and forwarded by the Assistant Commissioner of the North India Salt Revenue, Sambhar. It has been decided that further samples be collected after the rains, to be subjected also to chemical examination.

No. 1.—" Brine taken from new channel between Kyar No. 1 and Station, 10-15 A.M., 21st March 1891" (label).

The brine was pink in colour and slightly turbid, with a disagreeable odour. The specific gravity at 87° F. was 1·231.[1] The liquid boiled at a temperature of 107·5° Cent., and gave a decidedly alkaline reaction with litmus.

For the purposes of chemical analysis I have employed the methods and have taken advantage of the results obtained by Professor Dittmar in his elaborate examination of the samples of sea-water collected on the "Challenger" expedition. The total bases were estimated as sulphates, in which soda was determined by deducting the sum of the remaining sulphates, these latter in each case making a very small quantity. In the chlorine-estimation no attempt has been made to separate iodine or bromine; the result therefore is total halogen in each case. These remarks apply equally to the remaining samples of brine whose analyses are stated below.

The following is the composition of No. 1 :—

Water	70·950
Solids (by evaporation)	29·050
	100·000

Solids composed of—

Chlorine (Cl.)	13·991
Deduct oxygen-equivalent	3·153
Cl_2—O	10·838
Carbonic acid	·942
Sulphuric acid	2·093
Nitric acid	tr.
Soda	15·166
Lime	·004
Magnesia	tr.
Ferric oxide	tr.
	29·043

[1] The temperature at which this determination has been made is about an average temperature for liquids in Calcutta during about eight months in the year; and the rates at which solutions expand on increase of temperature being variable, it is impossible to make any safe correction to 60° F. On account also of the increase of the co-efficient of expansion of liquids at higher temperatures, determination of the specific gravities of liquids above 60° F. introduces a serious source of error.

Combining these acids and bases we obtain in 100 parts of brine—

Sodic chloride ($NaCl$)	10·84
„ carbonate (Na_2CO_3)	·94
„ sulphate (Na_2SO_4)	2·09
Calcic sulphate ($CaSO_4$)	15·18
	29·05

In one ton of the salts we have, therefore—

	cwt.	qr.	lb.
Sodic chloride	15	3	14
„ carbonate	1	2	7
„ sulphate	2	2	6
	19	3	27

No. 2.—"Brine taken from channels between Kyars Nos. 1 and 6. Time, 10 A.M.; 21st March, 1891" (label).

This specimen was tinged of a smoky colour, was turbid and with slight sediment at the bottom of the bottle. The same disagreeable smell referred to in No. 1 characterized this sample.

Specific gravity: 1·229 at 87° Fahr.

Boiling point: 108° Cent.

Results of *chemical analysis*:—

Water	71·245
Solids	28·755
	100·000

Solids composed of—

Chlorine	14·186
Deduct oxygen equivalent	3·196
Cl_2—O	10·990
Carbonic acid	·670
Sulphuric acid	2·122
Nitric acid	tr.
Soda	14·971
Lime	·003
Magnesia	—
Ferric oxide	tr.
	28·756

These acids and bases exist in the brine combined as—

Sodic chloride	23·375
„ carbonate	1·614
„ sulphate	3·759
Calcic sulphate	·007
	28·755

We have thus in one ton of dry residue—

	Cwt.	qr.	lb.
Sodic chloride	16	1	0
" carbonate	1	0	14
" sulphate	2	2	13
	19	3	27

No. 3.—"Brine selected from Kūl in Nalla sub-division, Gudha section. Time: 4-30 P.M.; 26th March, 1891."

This specimen was markedly colourless and clear, free from sediment and not possessing the same disagreeable smell noticed in the remaining samples.

Specific gravity: 1·110 at 88° Fahr.

Boiling point: 105° Cent.

Chemical analysis:—

Water	85·059
Solids	14·941
	100·000

Solids composed of—

Chlorine	7·446
Deduct oxygen equivalent	1·678
Cl_2—O	5·768
Carbonic acid	·140
Sulphuric acid	1·363
Soda	7·555
Lime	·030
Magnesia	·081
	14·937

These acids and bases are combined to form the following salts in 100 parts of the brine—

Sodic chloride	11·988
" carbonate	·337
" sulphate	2·352
Calcic sulphate	·073
Magnesic chloride	·191
	14·941

In one ton of salts, therefore, we have—

	Cwt.	qr.	lb.
Sodic chloride	16	0	5
" carbonate	0	1	23
" sulphate	3	0	16
	19	2	16

No. 4.—"Strong residue brine from a pan in the Ruparail sub-division of the Gudha section. Salt extracted from it on the 30th March, 1891. Time: 7-15 A.M.; 31st March, 1891."

Colour: Faint pink, slightly turbid.

Specific gravity: 1·253 at 88° Fahr.

This specimen like all the others exhibited an alkaline reaction with litmus. It boiled at 108° Cent.

Chemical composition—

Water . . .	69·190
Salts . . .	30·810
	100·000

Solids composed of—

Chlorine	13·192
Deduct oxygen equivalent	2·972
Muriatic acid (Cl_2—O.)	10·220
Carbonic acid .	·780
Sulphuric acid .	4·054
Nitric acid .	tr.
Soda . .	15·753
Lime . .	·007
Magnesia . .	tr.
	30·814

These combine to form—

Sodic chloride	21·737
„ carbonate	1·880
„ sulphate	7·176
Calcic sulphate	·017
	30·810

We have thus in one ton of solid residue—

	Cwt.	qr.	lb.
Sodic chloride	14	0	12
„ carbonate	1	0	25
„ sulphate	4	2	18
	19	3	27

In the above analyses I have stated the quantities in each case as anhydrous salts; sodic carbonate and sodic sulphate, for example, each in crystallizing retain 10 molecules of water to form $Na_2 SO_4$, 10 H_2O. (Glauber's salts) and Na_2CO_3 10 H_2O respectively. The amount, therefore, of crystallized material obtainable from the quantities of anhydrous salts would be increased in the case of sulphate of soda in the proportion of 142 to 322, and of carbonate of soda in the proportion of 106 to 286. Each of these salts, however, lose their water of crystallization on exposure to the air.

From the foregoing analyses it is possible to form a rough estimate of the order in which these salts crystallize from the concentrating brine. This is, of course, an important point in the separation of salts for commercial purposes. If the evaporation continued at a temperature of 87° Fahr. the point of saturation for sodium-chloride would be reached when the solution contained about 27 per cent of that salt, whilst a saturated solution and of sodium-sulphate at the same temperature would contain 32 per cent, and of sodium-carbonate 37 per cent, of the respective salts. These results are true for pure solutions and would be slightly different in the presence of other salts. It will thus be seen that in concentrating these brines sodium-chloride will be in each case the first salt to crystallize, followed in order by the sulphate and carbonate.

Substances present in small quantities. Besides the substances estimated quantitatively and mentioned above, I have found traces of *Iodine* and *Nitrates* in all four samples. The reactions for iodine were in some cases very decided; but I did not think it necessary to separate this element from the chlorine in stating the quantitative results.

Boracic acid. In 1889 Dr. H. Warth published his analyses of brines from the Sambhar Lake.[1] In describing these analyses he mentions the presence of boracic acid in sufficient quantities for estimation. Dr. Warth says (p. 215): "By a rough method I proved a yield of something like a half per cent. of crystallized borax in the dry residue of the lake brine." In an annual production of thirty lakh maunds of salt he estimates an output of 500 tons of borax, and mentions its cost in Europe as R1,000 per ton. This amount of borax would, of course, providing an economic method of separation be devised, prove of considerable commercial importance. I have, in consequence, taken special care in the detection of boracic acid; but in the samples of brine which have been submitted to me for analysis by the Commissioner of the North India Salt Revenue, *I have failed to detect a trace of boracic acid*, although I have employed, besides the usual delicate blowpipe-methods, a spectroscopic examination of the brines. In order to test the methods I adopted I prepared an artificial brine-residue by evaporating a solution of the salts estimated by Dr. Warth to contain 0·5 per cent. of borax. In this residue neither of the methods I employed failed to detect the presence of boracic acid in the mixture. I can only regret that Dr. Warth has given no further clue as to the process he employed beyond that it was "rough." I might suggest that a portion of what he terms "balance" in his analyses might consist of sulphate of lime and salts of magnesia (substances which he has not estimated) instead of borax. The price (R1,000 per ton) for borax can only be true for quantities smaller than one pound. Refined borax can be bought in London for less than half the above price.

2. *Crude Mineral oil from Burma.*

The following samples taken from different wells and forwarded by Dr. F. Noetling have been examined in the laboratory. With the exception of sample G the flashing point in each case was much below the temperature of the laboratory which averaged from 87° to 90° Fahr. In consequence of this high temperature the results are most seriously affected, especially in the distillation of the first fractions from which large quantities of the volatile hydrocarbons escape. Notwithstanding

[1] Warth: Recent Assays from the Sambhar Lake in Rajputana. *Rec., Geol. Surv., Ind.*, Vol. XXII (1889), page 214.

this source of error the loss is not unusually great in any sample. The use of a caoutchouc ring around the neck of the retort forms a vapour-tight joint with the condenser, and prevents any escape of vapours at the point where the temperature is always high. The high temperature of the laboratory introduces also a serious source of error in the specific gravity results. Although all determinations are corrected to 60° Fahr., the varying degrees of expansion of the different hydrocarbons as well as the increase in the coefficient at high temperatures makes any rule for correction little more than an approximation in which the inaccuracy is magnified by increase of temperature. I would, therefore, suggest that samples of oil be forwarded for examination only during the cold weather.

Of the eight samples sent by Dr. Noetling, seven present in general very similar characters, all possessing hydrocarbons of low boiling point and large quantities also of the solid paraffins. Sample G, however, taken from well No. 504 (Beme), possesses only small quantities of the lighter compounds; but in other respects is not very different from the remaining seven samples.

These oils contain such large quantities of solid hydrocarbons, besides oil which might be utilised for illuminating purposes, that a local industrial application of these heavier compounds might be a source of considerable profit. Four samples, D, E, G, H, contain free sulphuretted hydrogen, and all contain varying, though small, quantities of sulphur.

The following are the results obtained by an examination of the distillates from each sample:—

A.—KODOUNG: WELL NO. 1, 727 FEET.

Slightly viscous oil; dark green by reflected light; yellowish brown by transmitted light.

Specific gravity: ·8852 at 60° Fahr.

Flashing point: 60° Fahr. (Abel's test).

Fractions Nos. 1 and 2 distilling below 540° Fahr. were mixed and the more volatile hydrocarbons driven off by raising the temperature and passing a current of air through the liquid until the flashing point rose to 74° F. In this way, purified in the usual manner, I obtained 15 per cent. of illuminating oil with a specific gravity of ·802.

Fractional distillation.

		Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
	Oil distilling between					
1	164° F. and 468° F.	·7797	Colourless . .	10	8·80	
2	468° F. — 540° F.	·8243	Ditto . .	10	9·30	
3	540° F. and above .	·8515	Pale yellow . .	10	9·61	
4	......	·8656	Ditto . .	10	9·78	
5	......	·8730	Yellow . .	10	9·86	
6	......	·8763	Ditto . .	10	9·90	
7	......	·8652	Ditto . .	10	9·77	

		Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
	Oil distilling above 540° F.—contd.					
8	......	·8663	Deep yellow .	10	9·78	
9	......	...	......	...	...	The remainder, which was lost, solidified in the condenser.
10	Owing to an accident part of the distillate which had solidified in the condenser was lost; but the remainder on weighing was 12·8 per cent. of the material taken, or	...	......	...	12·80	
	10·40 per cent. loss.	...	......	...	10·40	
					100·00	

B.—KODOUNG: WELL NO. 16, 727 FEET.

Dark-green by reflected light; yellowish brown by transmitted light.

Flashing point: 68° Fahr. (Abel's test).

About 14 per cent. illuminating oil with a flashing point of 75° Fahr. and specific gravity of ·805: Large quantities of solid hydrocarbons.

Fractional distillation.

		Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
	Oil distilling between					
1	170·6° F.—469·4° F.	·7920	Colourless .	10	8·71	
2	469·4° F.—546·8° F.	·8378	Ditto	10	9·34	
3	546·8° F. & above.	·8592	Very pale yellow .	10	9·58	
4	......	·8705	Pale yellow .	10	9·70	
5	......	·8768	Yellow .	10	9·77	
6	......	·8778	Ditto .	10	9·78	
7	......	·8693	Ditto .	10	9·68	
8	......	·8718	Deep yellow .	10	9·72	Commenced to deposit paraffin at 89° F in feathery forms
9	......	·8664	Brownish yellow .	10	9·65	Ditto at 87° F.
10	......	...	......	...	5·87	
	Paraffin 'scale' .	...	......	...	·96	
	Coke . . .	...	......	...	4·52	
	Loss . . .	...	......	...	2·72	
					100·00	

C.—KODOUNG: WELL NO. 19, 359 FEET.

Dark-green by reflected light; yel'owish brown by transmitted light: Fairly mobile.

Specific gravity: ·889.

Flashing point: lower than 73° F.[1]

Illuminating oil: 14 per cent.: of specific gravity ·810, and flashing point of 73° F. Large quantities of solid and heavy hydrocarbons.

Fractional distillation.

		Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
1	180° F.—498° F. .	·7907	Nearly colourless .	10	8·89	
2	498° F. and above	·8392	Very pale yellow .	10	9·44	
3	......	·8633	Pale yellow . .	10	9·71	
4	......	·8741	Ditto . .	10	9·83	
5	......	·8807	Yellow . .	10	9·91	
6	......	·8830	Ditto . .	10	9·93	
7	......	·8652	Ditto . .	10	9·73	
8	......	·8737	Deep yellow .	10	9·82	Began to deposit solid paraffin at 89° F. in feathery forms.
9	......	·8912	Ditto .	10	10·03	Began to deposit solid paraffin at 87° F. in feathery crystals.
10	......	...	......	...	5·54	
	Paraffin 'scale' .	...	......	...	1·20	
	Coke . . .	...	......	...	3·15	
	Loss . . .	...	......	...	2·82	
					100·00	

D.—TWINGON: WELL NO. 167, 310 FEET.

Specific gravity: ·873 at 60° F.

Dark-green by reflected light; yellowish brown by transmitted light: Slightly viscous. Smells of sulphuretted hydrogen.

Illuminating oil: about 17 per cent., of specific gravity ·809, and flashing point of 75° Fahr.

Fractional distillation.

		Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
	Oil distilling between					
1	183° F. and 491° F.	·7914	Colourless . .	10	9·06	
2	491° F. and 561° F.	·8322	Very pale yellow .	10	9·53	
3	561° F. and above	·8567	Pale yellow .	10	9·81	

[1] In determining the flashing point of an oil which gives off inflammable vapour at a temperature much below that of the laboratory, the artificial cooling of the oil involves a condensation from the air of large quantities of moisture which interferes with the experiment. I have in consequence not determined the flashing (except the first two) of oils flashing below 73° Fahr.

		Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
	Oil distilling between—contd.					
4	......	·8673	Yellow . .	10	9·94	
5	......	·8718	Ditto . .	10	9·99	
6	......	·8775	Ditto . .	10	10·05	
7	......	·8730	Ditto . .	10	10·00	
8	......	·8664	Deep yellow .	10	9·92	Commenced to deposit paraffin at 88·5.
9	......	·8670	Brownish yellow .	10	9·93	Commenced to deposit paraffin at 90·5 F.
10	......	...	......	...	3·28	
	Paraffin 'scale' .	...	......	...	2·72	
	Coke . . .	...	......	...	3·18	
	Loss . . .	...	......	...	2·59	
					100·00	

E.—TWINGON: WELL NO. 306, 195 FEET.

Slightly viscous oil; dark-green in colour and smelling strongly of sulphuretted hydrogen.

Specific gravity: ·875 at 60° Fahr.

Illuminating oil: about 18 per cent., of specific gravity ·801, and flashing point of 76° Fahr.

Fractional distillation.

		Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
	Oil distilling between					
1	195° F.—468° F. .	·7822	Colourless . .	10	8·94	
2	468° F.—532° F. .	·8224	Very pale yellow .	10	9·42	
3	532° F. and above	·8519	Ditto .	10	9·73	
4	......	·8660	Pale yellow . .	10	9·89	
5	......	·8717	Yellow . .	10	9·96	
6	......	·8769	Ditto . .	10	10·02	
7	......	·8712	Ditto . .	10	9·95	
8	......	·8584	Deep yellow .	10	9·81	
9	......	·8586	Ditto .	10	9·81	
10	......	...	......	...	4·40	Solid.
	Paraffin 'scale' .	...	......	...	2·47	
	Coke . . .	...	......	...	3·23	
	Loss . . .	...	......	...	2·37	
					100·00	

F.—TWINGON: WELL NO. 374, 280 FEET.

Slightly viscous oil; dark green.

Specific gravity: ·882 at 60° Fahr.

Illuminating oil: about 18 per cent., of specific gravity ·809, and flashing point of 74° Fahr: Large quantities of heavy hydrocarbons.

Fractional distillation.

		Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
	Oil distilling between					
1	181° F. and 482° F.	·7894	Colourless . .	10	8·95	
2	482° F. and 559° F.	·8339	Very pale yellow .	10	9·45	
3	559° F. and above.	·8577	Ditto .	10	9·72	
4	......	·8678	Pale yellow . .	10	9·84	
5	......	·8736	Ditto . .	10	9·90	
6	......	·8772	Ditto . .	10	9·94	
7	......	·8671	Yellow . .	10	9·83	
8	......	·8572	Deep yellow .	10	9·72	
9	......	·8647	Ditto .	10	9·80	Commenced to deposit paraffin at 89° F.
10	......	...	......	..	4·44	
	Paraffin 'scale' .	...	......	...	1·45	
	Coke . . .	...	......	...	3·63	
	Loss . . .	...	......	...	3·33	
					100·00	

G.—BEME: WELL NO. 504, 100 FEET.

Dark-green; rather viscous oil; smelling strongly of sulphuretted hydrogen.

Specific gravity: ·897 at 60° Fahr.

Flashing point: 132° Fahr.

A very small quantity indeed was available for illuminating purposes; but the oil is very rich in the heavier hydrocarbons.

Fractional distillation.

		Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
	Oil distilling between					
1	190° F. and 514° F.	·8254	Very faint yellow..	10	9·20	
2	514° F. and above.	·8534	Pale yellow . .	10	9·51	
3	......	·8702	Ditto . .	10	9·70	
4	......	·8798	Ditto . .	10	9·80	
5	......	·8875	Yellow . .	10	9·89	
6	......	·8889	Deep yellow .	10	9·91	

		Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
	Oil distilling between—contd.					
7	......	·8871	Brownish yellow .	10	9·89	
8	......	·8840	......	10	9·85	Deposits paraffin at 86° F.
9	......	·8829	......	10	9·84	Ditto at 88° F.
10	......	...	......	...	3·79	
...	Paraffin 'scale' .	...	......	...	2·69	
...	Coke . . .	...	......	...	3·59	
...	Loss . . .	...	......	...	2·34	
					100·00	

H.—BEME: WELL NO. 516, 100 FEET.

Dark-green oil, containing large quantities of sulphuretted hydrogen.

Specific gravity: ·902 at 60° Fahr.

Illuminating oil: about 7 per cent., of specific gravity ·812, and flashing point of 79° Fahr.

Fractional distillation.

		Specific gravity at 60° F.	Colour by transmitted light.	Per cent. by volume.	Per cent. by weight.	REMARKS.
	Oil distilling between					
1	172° F.—518° F. .	·8337	Faint tinge of yellow.	10	9·23	
2	518° F.—572° F. .	·8572	Very pale yellow .	10	9·50	
3	572° F. and above .	·8707	Pale yellow . .	10	9·65	
4	......	·8817	Ditto . .	10	9·77	
5	......	·8896	Ditto . .	10	9·85	
6	......	·8968	Ditto . .	10	9·94	
7	......	·8940	Brownish yellow .	10	9·91	
8	......	·8896	Deep brown .	10	9·86	
9	......	·8955	......	10	9·93	Deposited paraffin at 89° F.
10	......	...	......	...	4·03	
...	Paraffin 'scale' .	...	......	...	2·15	
...	Coke . . .	...	......	...	4·23	
...	Loss . . .	...	......	...	1·35	
					100·00	

3 *Further Assays and Determinations.*

Substance.	For whom.	Result.
5 specimens of quartz, from the Mount Ophir concession in Johore, Kadana District, for gold.	DYCE NICOL & Co., Calcutta.	Assayed for gold.
2 specimens of chalcopyrite and iron-pyrite, from Sikkim, for copper.	P. N. BOSE, Geological Survey of India.	Specimen G., chalco-pyrite and iron-pyrite, in clay-slate. Quantity received, 2 oz. Contains 6·38 per cent. of copper (Cu.). Specimen J., chalco-pyrite and iron-pyrite, with quartz and schist. Quantity received, 4 oz. Contains 12·21 per cent. of copper (Cu.).
2 specimens of coal, for assay.	MACNEILL & Co., Calcutta.	Proximate analyses and calorific powers determined.
Coal, from the Pench R., Chindwara, for sulphur.	The Chief Commissioner, P. W. D., Central Provinces.	'Pit No. 2, near Col. Ashburner's well. Contains ·46 per cent. of sulphur.
Tin-ore, washed from tin soil, Maliwoon, Mergui District, for tin.	DR. H. WARTH, Offg. Superintendent, Government Central Museum, Madras.	Quantity received, 38 grains. Yielded on assay an appreciable trace of tin.
Galena, from the Mandalay District, Upper Burma, for lead and silver.	W. F. NOYCE, Secretary to the Financial Commissioner, Burma.	Quantity received, 14½ oz. Yielded on assay 39·67 per cent. of lead; 6 oz. 0 dwts. 20 grs. of silver to the ton of lead, and a minute trace of gold.
Coal from Karharbari, for assay.	C. W. GRAY, Superintendent, Bengal Coal Co., Ld., Calcutta.	Proximate analysis and calorific power determined.

Galena, with quartz, from Motabarria, near Bhagulpur.	Dyce Nicol & Co., Calcutta.	Assayed for lead, silver, and gold.		
		Locality, &c.	*Quantity received.*	*Yielded on assay.*
Specimens of tin-ore from Maliwoon, South Burma, for tin.	T. W. H. Hughes, Geological Survey of India.	Maliwoon, Kamong, Pit No. 1, gravel 120 lbs.	3967·66 grs.	72·93 per cent. of tin.
		" " " 2	4284·02 "	70·91 "
		" " " 3	3466·11 "	74·66 "
		" " " 4	5794·85 "	75·34 "
		" " " 5	5331·88 "	69·70 "
		" " " 6	2486·15 "	74·06 "
		" " " 7	7563·39 "	70·34 "
		" " " 8	4676·00 "	73·20 "
		" Camp II, " 13	439·82 ,	70 78 "
		" " " 14	524·70 "	62 70 "
		" " " 15	797·85 "	50·97 "
		" " " 16	1327·18 "	49·52 "
		" " " 17	1149·71 "	67·62 "
		" " " 19	1037·05 "	63·00 "
		" " " 21	783·96 "	66·67 "
		" Sample No. 1	2981·53 "	65·67 "
		" Hill No. 1, Tin-ore from 7,000 lbs. gravel	53578·52 "	61 87 "
		" " 2 " 3,500 "	75718·37 "	50 10 "
		" " 2 " 1,750 "	26077·55 "	59·20 "

Specimens examined.

For whom.	Locality.	REMARKS.
V. L. REES, Calcutta	Durjang, Bumai	Biotite schist and gneiss with garnets.
W. COLDSTREAM, Simla	Banni and Angi villages, Simla District.	Quartz with copper-pyrite and iron-pyrite, shale, quartz and pyrite.
A. M. GOW SMITH	Sikkim	Kaolin with small quantity of carbonate of lime.
T. W. H. HUGHES	Metamorphics of the Seroncha District.	Corundum: Hardness nearly 9: Colour, dark cinnamon-red; specific gravity, 3·9440 at 60° F. (3·9535 at 85° F.). Cleavage, basal (oP.) and rhombohedral (R.) Form: basal plane (oP.) and steep pyramid 9-2 (Dana). Lustre: vitreous on cleavage-faces.
QUARTER-MASTER-GENERAL, Intelligence Branch, Simla.	Mountain in the salt desert, South East Persia.	Large number of small specimens of chalcedonic amygdules, probably from some vesicular trap-rock. Two large specimens of impure jasper. One of pink gypsum with small quantities of carbonate of lime. Bottle-green piece of calcite, from marble quarries near Yezd.
G. B. REYNOLDS	Warora Colliery	Specimens of clay, and bricks made from the same, tested at a white heat with the following results:— No. 1. Tile made of same clay as No. 2, but more finely sifted. A chip with sharp edges, exposed to a white heat, showed no signs of fusion; specimen strong and fairly compact.
No. 2. Taper brick made of the white clay overlying coal at Warora, ½ raw clay, ½ burnt.	....	„ 2. Less compact. Showed no sign of fusion.
No. 3. Brick made of material similar to Nos. 1 and 2, but blackened inside.	....	
No. 4. Broken piece of brick, made of some black clay in the pit.	....	„ 4. Very porous and friable.
No. 5. Raw clay	....	„ 5. Completely fused into a vesicular mass.
No. 6. Bottom clay, raw, No. 2 seam.	....	„ 6. Slight fusion. At white heat edges sharp, surface slightly vitrified, compact. Colour changed to light grey on surface, but remained black inside.
No. 7. Middle band, raw, No. 2 seam.	....	„ 7. Similar results.
No. 8. Middle band, raw, No. 3 seam.	....	„ 8. Ditto. Not so compact and strong as Nos. 6 and 7. The black colour probably due to the action of carbonaceous matter, which is present, having reduced the iron to the condition of magnetic oxide.
H. M. BECHER, Singapore	Jani, Meerut District	Augite in cavity in rock-specimen. Faces exhibited: (∞P.) (110), ∞P̶∞. (010), P. (111), 2P. (221), ∞P̶∞ (100), ∞2P. (120).

Notifications by the Government of India during the months of August, September and October 1891, published in the "Gazette of India;" Part I.—Appointment, Confirmation, Promotion, Reversion and Retirement.

Department.	Number of order and date.	Name of officer.	From	To	Nature of Appointment, &c.	With effect from	Remarks.
Revenue and Agricultural Department.	$\frac{2416}{111}$ S., dated 28th October 1891.	W. B. D. Edwards.	...	3rd grade Assistant Superintendent.	Substantive.	20th October 1891.	

Annual Increments to Graded Officers sanctioned by the Government of India during August, September and October 1891.

Name of Officer.	From	To	With effect from	No. and date of sanction.	Remarks.
	R	R			
C. L. Griesbach . . .	850	900	1st August 1891.	Revenue and Agricultural Department, No. $\frac{1874}{8}$ S., dated 11th August 1891.	
T. H. Holland . . .	350	380	3rd August 1891.	Revenue and Agricultural Department, No. $\frac{1912}{36}$ S., dated 17th August 1891.	

Postal and Telegraphic Addresses of Officers.

Name of Officer.	Postal address.	Nearest Telegraph Office.
T. W. H. HUGHES	Mergui	Tavoy.
C. L. GRIESBACH . . .	Mandalay . . .	Mandalay.
R. D. OLDHAM	Calcutta	Calcutta.
P. N. BOSE	Mergui	Tavoy.
T. H. D. LATOUCHE . . .	Mohpani, C. P. . .	Gadarwara.
C. S. MIDDLEMISS . . .	Abbottabad . . .	Abbottabad.
W. B. D. EDWARDS . . .	Do.	Do.
P. N. DATTA	Thayetmyo . . .	Thayetmyo.
F. NOETLING	Mogaung . . .	Mogaung.
HIRA LAL	Abbottabad . . .	Abbottabad.
KISHEN SINGH	Calcutta	Calcutta.

ADDITIONS TO THE MUSEUM.

FROM 1ST OCTOBER TO 31ST DECEMBER 1890.

A specimen of pyrrhotite in quartz, from 40 miles south of Ranchi, Chota Nagpur.
PRESENTED BY R. R. WALLER.

Agate-like layers formed in silicate of soda.
PRESENTED BY COL. J. WATERHOUSE.

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FROM 1ST OCTOBER TO 31ST DECEMBER 1890.

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BAYBERGER, *Emmeran.*—Physikalische und Geologische Verhältnisse des Chiemsees. 8° Pam. Leipzig, 1890.

BIGOT, *A.*—L'Archéen et le Cambrien dans le Nord du Massif Breton et leurs équivalents dans le Pays de Galles. 8° Cherbourg, 1890.

BLANCKENHORN, *Max.*—Beiträge zur Geologie Syriens: Die Entwickelung des Kreidesystems in Mittel-und-Nord-Syrien mit besonderer Berücksichtigung der paläontologischen Verhältnisse nebst einem anhang über den jurassischen Glandarienkalk. 4° Cassel, 1890.

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BRONN'S Klassen und Ordnungen des Thier-Reichs. Band IV, Würmer, lief. 15-16; and Band V, Abth. II, lief. 28. 8° Leipzig, 1890.

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CLARK, *John Willis*, and HUGHES, *Thomas McKenny.*—The life and letters of the Rev. Adam Sedgwick. Vols. I-II. 8° Cambridge, 1890.

CONOLLY, *Arthur.*—Journey to the north of India, overland from England through Russia, Persia and Affghaunistaun. 2nd edition. Vols. I-II. 8° London, 1838.

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DREYER, *Friedrich.*—Die Tripoli von Caltanisetta (Steinbruch Gessolungo) auf Sizilien 8° Jena, 1890.

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" Quarterly Indian Army List. New series, No. 5. 8° Calcutta, 1890.
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